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Notice

Town of Liberty Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Abstract

Together with the Town of Liberty (Liberty), Booz Allen Hamilton has completed the feasibility study for a proposed microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not Phase III funding and additional subsidies. The commercial and financial viability of the project have been analyzed and detailed in this document. The Liberty microgrid project faces the challenge of high capital costs, but it benefits from an advantageous mix of generation and loads. A new 150 kilowatt (kW) rooftop solar photovoltaic (PV) array, a new 450 kW carport solar PV array, a diesel backup generator, three 1 megawatt (MW)/ 4 megawatt-hour (MWh) battery storage units, and one existing 70 kW solar PV array will provide reliable, low-emission electricity to customers while providing a proof of concept for a community microgrid in investor-owned utility (IOU) territory. Many of the takeaways of the feasibility study may be generalized across the spectrum of NY Prize and community microgrids.

Keywords: NY Prize, NYSERDA, distributed energy resources (DERs), energy resilience, clean energy, DER, Liberty

Contents

Figures

Tables

Acronyms and Abbreviations

AC	Alternating Current
AMI	Advanced Metering Infrastructure
ATS	Automatic Transfer Switch
BCA	Benefit Cost Analysis
BEMS	Building Energy Management Systems
BTU	British thermal unit
CAIDI	Customer Average Interruption Duration Index
CHP	Combined Heat and Power
DC	Direct Current
DER	Distributed Energy Resources
DNP3	Distributed Network Protocol
DR	Demand Response
DSP	Distributed System Platform
EE	Energy Efficiency
EMS	Energy Management System
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
Hz	Hertz
ICCP	Inter-Control Center Communications Protocol
IEc	Industrial Economics
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor-Owned Utility
ISM	Industrial Scientific and Medical
IT	Information Technology
ITC	Investment Tax Credit
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
LAN	Local Area Network
LBMP	Location-Based Marginal Price
LED	Light-Emitting Diode
Mcf	One Thousand Cubic Feet of Natural Gas
MCS	Microgrid Control System
MHz	Megahertz
MMBTU	One Million British Thermal Units
$MMTCO_2e$	Million Metric Tons CO_2 Equivalent
$MTCO_2e$	Metric Tons CO_2 Equivalent
MW	Megawatt
MWh	Megawatt-hour
NYISO	New York Independent System Operator
NYPSC	New York Public Service Commission
NYS DEC	New York State Department of Environmental Conservation

NYSEG	New York State Electric and Gas Corporation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PV	Photovoltaic
QF	Qualifying Facility
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCOPF	Security Constrained Optimal Power Flow
SOA	Service Oriented Architecture
SOW	Statement of Work
SPV	Special Purpose Vehicle
TCP/IP	Transmission Control Protocol/Internet Protocol
T&D	Transmission and Distribution
VAC	Volt Alternating Current

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority (NYSERDA) through its New York Prize initiative to conduct a feasibility study of a community microgrid concept in the Town of Liberty. This deliverable presents the findings and recommendations from the previous four tasks, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. The design demonstrates that the Town can improve energy resilience with intentional and emergency island mode capabilities and comply with the greater New York REV (Reforming the Energy Vision) program by constructing 600 kW of clean energy generation capability. The study concludes that the technical design is feasible, however it is financially infeasible as a standalone project.

The Liberty microgrid project will tie together six critical facilities (per NYSERDA's definition), and four adjacent load groupings of mixed residential and commercial facilities. Table ES-1.Table ES-1 lists all the facilities under consideration for the microgrid concept at this time, and Figure ES- 1 shows their locations in Liberty.

Table ES-1. Prospective Microgrid Facilities

Table lists the facilities and load clusters included in the Town of Liberty's proposed microgrid, including their classifications and whether they are critical or important. Table also provides their labels for Figure ES-1.

Name on Map	Property	Classification
F1	Town Government Center	Public*
F2	Liberty Police Department and Village Office	Public*
F3	Liberty Public Library	Public*
F4	Liberty Elementary School	Public*
F5	Sun Gate Mini Mart and Gas Station	Commercial*
F6	Great American (Supermarket)	Commercial*
F7	Load Cluster 1	Residential**
F8	Load Cluster 2	Residential**
F9	Load Cluster 3	Residential**
F10	Load Cluster 4	Residential**
	* Critical Facility ** Important Facility	

In order to meet the energy needs of these critical and important facilities, the microgrid system will incorporate the following existing and proposed generation assets outlined in Table ES-2 below.

Table ES-2. Liberty Generation Assets

Distributed energy resources that will be included in the Liberty microgrid, including their address, fuel source, and nameplate capacity. The table also provides their labels for Figure ES-1.

Map Label	Description	Fuel Source	Capacity (kW)	Address
DER1	**Existing solar PV array**	Sun Light	70	201 N. Main St
DER2	**New roof-top solar PV array**	Sun Light	150	201 N. Main St
DER3	**New backup generator**	Diesel	200	201 N. Main St
DER4	**New carport solar PV array**	Sun Light	450	201 N. Main St
DER5	**New zinc air battery unit**	N/A	1 MW/4 MWh	201 N. Main St
DER6	**New zinc air battery unit**	N/A	1 MW/4 MWh	201 N. Main St
DER7	**New zinc air battery unit**	N/A	1 MW/4 MWh	201 N. Main St

Figure ES-1. Schematic of Microgrid with Facilities and DERs

Figure shows the proposed microgrid and the locations of the facilities and DERs in the Liberty microgrid. Existing DERs are marked as blue stars and new/proposed DERs are marked as yellow stars. Facilities are marked as red points.

The proposed DERs will typically have adequate capacity to supply all of the microgrid facilities in Table ES-1 with electricity in island mode. When the solar arrays are operating close to their maximum production points, the microgrid's generation capacity will approach 670 kW, with an additional 200 kW of spinning support from the diesel backup generator. Aggregate demand from microgrid facilities averaged 231 kW and never exceeded 504 kW in 2014.[1] The backup power supplied by the microgrid will ensure essential services remain accessible during long-term grid outages, providing relief for residents in and around the Town of Liberty. With the addition of these generation assets, the Town could experience reduced emissions during peak demand events and could benefit from a more resilient and redundant energy supply to critical services.

The proposal envisions hybrid ownership, wherein a special purpose vehicle (SPV) owns the distributed energy resource assets and New York State Electric and Gas Corporation (NYSEG) owns the microgrid and distribution infrastructure. The Project Team believes this hybrid model offers the greatest benefits and flexibility to the utility and customer base within the Town.

Given the capital expenditures, it is anticipated that the SPV will be owned by private investors. NYSEG has not indicated a preference for ownership of the electrical hardware necessary, the Project Team has assumed they will own the additional hardware upgrades required as all components will be added to existing NYSEG infrastructure. Further, NYSEG may leverage its energy domain expertise to operate and maintain the microgrid or a third party operator could provide the service such as Constellation or Con Ed Solutions. The operator will have significant influence over DER operation through the microgrid control system (MCS), but the SPV will develop the operating strategy for the battery storage units, which are capable of performing energy arbitrage and providing ancillary services to the larger grid. The SPV shareholders will receive revenue from electricity sales to the utility and participation in ancillary service markets. Revenues streams from electricity sales will accrue to SPV investors and but will not cover variable generation costs. With NY Prize Phase III funding and additional operating subsidies, the community microgrid in the Town of Liberty is feasible and will help maintain critical services to the community and extend resilient electrical service to a low and moderate income community.

The microgrid will incur initial capital costs of $4.9 million as well as yearly operation and maintenance (O&M) costs totaling $130,000 per year. Overall revenue streams from the project are estimated at $85,000 per year this includes approximately $40,000 in revenue from the battery storage units and $45,000 in electricity sales from the solar arrays. The proposed microgrid's commercial feasibility depends on NY Prize Phase III funding and additional operating subsidies. On an annual basis, costs will exceed revenues, and when capital

[1] This estimate was calculated by summing each facility's peak demand from 2014. The estimate therefore assumes that all facilities reached peak demand at the same time, which is unlikely. The true peak demand was almost certainly less than 504 kW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

expenditures are included, the project does not cover its total costs even with NY Prize Phase III grant money.

The Liberty microgrid concept, with new reliable and renewable generation and the integration of existing energy resources, provides the Town with an energy resilience solution that is technically sound and, with the NY Prize and operating subsides, financially viable. The ability to island six critical facilities (per NYSERDA's definition), and four adjacent load groupings is a significant addition to the resilience of the Town in times of emergency and extended grid outages.

1. Introduction

The Town of Liberty (Liberty) is seeking to develop a community microgrid to improve energy service resilience, accommodate distributed energy resources, and reduce greenhouse gas (GHG) emissions. Working with Liberty and NYSEG, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that will connect six critical facilities and four adjacent load groupings with three new generation assets and one existing solar PV array.

The design proposes a new 150 kW solar PV rooftop array, 450 kW carport solar PV array, 200kw diesel backup generator, and three 1 MW/4 MWh zinc air battery units at Liberty Elementary School. The design also incorporates one existing 70 kW solar PV array located at Liberty Elementary School. Section 2 of this document describes the configuration further. In this document, the Project Team discusses the observations, findings, and recommendations from the entirety of the analysis. Within the document, Booz Allen also explores avenues for further development, discusses project results, and shares lessons learned regarding configuration, capabilities, environmental and economic benefits, and implementation scenarios.

2. Microgrid Capabilities and Technical Design and Configuration

This section provides a combined overview of the criteria assessed in Task 1 - Microgrid Capabilities and Task 2 – Technical Design and Configuration. The tasks were combined and address all of the criteria in the following order: microgrid capabilities, DER characterization, load characterization, proposed microgrid infrastructure and operations, electric and thermal infrastructure characterization, microgrid building and controls, and IT and telecommunications infrastructure.

2.1 Project Purpose and Need

Liberty faces several challenges that could be resolved with a community microgrid:

- The Town Government Center, Liberty Elementary School, and Police Department/Village Office complex do not have access to emergency back-up generation. A microgrid could ensure that these critical facilities have a stable, reliable power supply for a multi-day power outage by tying solar PV arrays to battery storage units.
- Electricity service in the region has occasionally been interrupted by extreme weather events such as Hurricane Sandy and multiple winter storms. A microgrid could provide electricity to critical facilities during extreme weather events, and may expand in the future to include more homes, businesses, and government buildings.
- Liberty experiences non-storm related interruptions to grid power. The Town is within a NYSEG-identified load pocket noted for power and voltage challenges that may require

infrastructure upgrades to ensure power reliability; it is not confirmed that the distribution lines the proposed microgrid will be leveraging will directly support infrastructure cost deferral. The area occasionally experiences unpredictable smaller outages that can last minutes or hours. A microgrid could provide needed stability to local municipal and commercial facilities.

- In order to improve its energy profile and reduce its carbon footprint, the community prefers low-emission options for distributed energy resources. An integrated microgrid that includes battery storage units adds value to advanced distributed energy resource technologies, increasing the viability of intermittent renewable energy sources such as solar arrays.

The absence of natural gas infrastructure in Liberty prevented the use of reliable, low emission DERs such as combined heat and power (CHP) units and fuel cells. The design instead relies on storage units, solar PV arrays, and load management to maintain continuous power supply in island mode. Although expensive, these DERs will make the energy supply in Liberty more resilient and will lessen the strain on the local electricity distribution network by reducing the need for power imports during peak demand events.

2.2 Microgrid Required and Preferred Capabilities (Sub Tasks 1.1 and 1.2)

The NYSERDA statement of work (SOW) 65583 outlines 15 required capabilities and 18 preferred capabilities each NY Prize microgrid feasibility study must address. Table 1 summarizes required and preferred capabilities met by the proposed microgrid design in greater detail.

Table 1. Microgrid Capabilities Matrix

Table lists NYSERDA's required and preferred capabilities and annotations of whether or not the Liberty microgrid will meet these criteria.

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Serves more than one, physically separated critical facilities	Required	Y
Primary generation source not totally diesel fueled	Required	Y
Provides on-site power in both grid-connected and islanded mode	Required	Y
Intentional islanding	Required	Y
Seamless and automatic grid separation/restoration	Required	Y
Meets state and utility interconnection standards	Required	Y
Capable of 24/7 operation	Required	Y
Operator capable of two-way communication and control with local utility	Required	Y
Load following while maintaining the voltage and frequency when running in parallel to grid	Required	Y
Load following and maintaining system voltage when islanded	Required	Y
Diverse customer mix (residential, commercial, public)	Required	Y
Resiliency to wind, rain, and snow storms	Required	Y
Provide black-start capability	Required	Y
Energy efficiency upgrades	Required	Y
Cyber secure and resilient to cyber intrusion/disruption	Required	Y
Microgrid logic controllers	Preferred*	Y
Smart grid technologies	Preferred*	Y
Smart meters	Preferred	N
Distribution automation	Preferred*	Y
Energy storage	Preferred	Y
Active network control system	Preferred*	Y
Demand response (DR)	Preferred	Y
Clean power sources integrated	Preferred	Y
Optimal power flow (OPF) (economic dispatch of generators)	Preferred	Y
Storage optimization	Preferred	Y
PV observability, controllability, and forecasting	Preferred	Y
Coordination of protection settings	Preferred	Y
Selling energy and ancillary services	Preferred	Y
Data logging features	Preferred	Y
Leverage private capital	Preferred	Y
Accounting for needs and constraints of all stakeholders	Preferred	Y
Demonstrate tangible community benefit	Preferred	Y
Identify synergies with Reforming the Energy Vision	Preferred	Y
* capability is characterized as preferred by NYSERDA but is a required component in this design		

The sections that follow address how the microgrid will meet these capabilities in more detail.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

Liberty and the Booz Allen team have identified six facilities and four groups of residential units that will be connected to the microgrid. All six of the connected facilities will provide critical services to the community in the case of an outage. See Table ES-1 for a full list of prospective facilities to be tied into the microgrid.

The proposed microgrid footprint occupies approximately 23 acres in Liberty. Loads will be interconnected via the existing medium voltage (4.8 kV) NYSEG power line along North Main

Street. Distributed microgrid equipment and control software will communicate over NYSEG's WAN utilizing the existing IT fiber optic backbone. Utilizing industry standard protocols, such as Distributed Network Protocol (DNP3), Open Platform Communication (OPC), Modbus, 61850, and Inter-Control Center Communications Protocol (ICCP) (IEC 60870-6) will enable the remote monitoring and control of distributed devices, regardless of manufacturer. The microgrid design is flexible and scalable to accommodate future expansion and technologies.

2.2.2 Limited Use of Diesel Fueled Generators

Solar energy is the primary energy source for the Liberty microgrid. Combined with 12 MWh of battery storage, solar energy will provide relatively reliable energy throughout the year. However, in a long-term outage scenario the lack of natural gas infrastructure in Liberty will limit the supply of energy to battery charge, available sunlight, and stockpiled diesel fuel. The diesel generator will only come on-line when the batteries have exhausted their charge and the solar arrays are not producing electricity. When the diesel generator comes on-line, it will operate continuously, charging the batteries when its production exceeds microgrid demand. When aggregate demand exceeds the generator's capacity, the batteries will discharge enough current to meet demand. It is important to note the MCS will deploy solar energy whenever it is available, which should minimize use of the diesel generator.

The Project Team expects the diesel generator will likely need to operate for 40 hours in order for the microgrid to provide seven days of continuous energy to all facilities.[2] The generator will therefore be equipped with a 1020 gallon storage tank.[3]

Diesel was chosen as the backup generation given the greater accessibility and ease of storage of diesel fuel versus propane or other backup power sources. Moreover, diesel generators have the ability to ramp from zero to full capacity almost instantaneously, whereas small gas fired engines do not exhibit comparable ramping speeds. The diesel generators will be Tier 4 certified, with emissions up to 90% less than legacy diesel engines[4].

2.2.3 Local Power in both Grid-Connected and Islanded Mode

The microgrid will provide on-site power in both grid-connected and islanded mode. In island mode, the MCS will optimize charge and discharge of battery storage units to maintain stable and reliable power flow. The control system is capable of shedding the supermarket, gas station, public library, and Load Clusters 1-2 in real time. Load shedding is crucial to the successful operation of the Liberty microgrid, as the supply of energy in island mode is limited by battery charge and availability of sun light. In grid-connected mode, the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the larger NYSEG grid when economic and technical conditions align.

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[2] The diesel generator will not need to operate for the microgrid to provide seven days of continuous energy after shedding loads.

[3] Assuming ~70 gallons per MWh, this storage tank should allow ~70 hours of operation.

[4] EPA Tier 4 diesel engine standards: http://www3.epa.gov/otaq/nonroad-diesel.htm.

The solar arrays will stay online throughout the year, selling electricity to NYSEG in grid-connected mode. The battery storage units may engage in some degree of energy arbitrage, frequency regulation, or peak shifting on a daily basis, but must maintain a high level of charge to provide for emergency outages. The backup diesel generator will come on-line in island mode as necessary to meet microgrid load.

2.2.4 Intentional Islanding

The microgrid will intentionally switch to island mode when doing so will result in a more stable and reliable environment. Transitions to island mode will comply with New York State standardized interconnection requirements as well as local utility and building codes, which will ensure equipment and personnel safety throughout each phase of the switch.

Upon a command from the system operator, the MCS will automatically start and parallel the generation assets. Once the available power sources are synchronized with the grid (and each other), the system is ready to disconnect from the larger grid, and will open the incoming utility line breaker. After completing the transition to island mode, the MCS must maintain system voltage and frequency between acceptable limits and adjust output from the battery storage units to match aggregate load.

Because the Liberty microgrid is located at the end of a feeder line, it will not disconnect any downstream non-microgrid loads when it operates in island mode. The microgrid therefore has the capability to switch to island mode to participate in DR programs or to beat high electricity prices during peak demand events.

2.2.5 Resynchronization to NYSEG Power

When operating in island mode, the microgrid will constantly monitor the status of the larger grid and will re-connect when conditions have stabilized. Signals from the MCS will prompt re-connection when monitored operational variables on the larger grid satisfy predetermined conditions. The MCS will be capable of both automatic and manual re-connection using synchronization and protection equipment.

The microgrid design requires a new automated switch along North Main Street to serve as the point of common coupling (PCC) between the microgrid and NYSEG's system. The control system will trigger the opening or closing of this breaker, as appropriate, during system transitions.

2.2.6 Standardized Interconnection

The microgrid design complies with New York Public Service Commission (NYPSC) interconnection standards. Table 2 outlines the most significant state interconnection standards that apply to this microgrid project. Customers that wish to connect DERs to NYSEG's system must follow the same New York State Standard Interconnection Requirements identified in Table 2.

Table 2. New York State Interconnection Standards

Table outlines New York State interconnection standards by category (common, synchronous generators, induction generators, inverters, and metering) and a description of the standard.

Standard Category	Description
Common	Generator-owner shall provide appropriate protection and control equipment, including a protective device that utilizes an automatic disconnect device to disconnect the generation in the event that the portion of the utility system that serves the generator is de-energized for any reason or for a fault in the generator-owner's system
	The generator-owner's protection and control scheme shall be designed to ensure that the generation remains in operation when the frequency and voltage of the utility system is within the limits specified by the required operating ranges
	The specific design of the protection, control, and grounding schemes will depend on the size and characteristics of the generator-owner's generation, as well as the generator-owner's load level, in addition to the characteristics of the particular portion of the utility's system where the generator-owner is interconnecting
	The generator-owner shall have, as a minimum, an automatic disconnect device(s) sized to meet all applicable local, state, and federal codes and operated by over and under voltage and over and under frequency protection
	The required operating range for the generators shall be from 88% to 110% of nominal voltage magnitude
	The required operating range for the generators shall be from 59.3 hertz (Hz) to 60.5 Hz
Synchronous Generators	Requires synchronizing facilities, including automatic synchronizing equipment or manual synchronizing with relay supervision, voltage regulator, and power factor control
	Sufficient reactive power capability shall be provided by the generator-owner to withstand normal voltage changes on the utility's system
	Voltage regulator must be provided and be capable of maintaining the generator voltage under steady state conditions within plus or minus 1.5% of any set point and within an operating range of plus or minus 5% of the rated voltage of the generator
	Adopt one of the following grounding methods: • Solid grounding • High- or low-resistance grounding • High- or low-reactance grounding • Ground fault neutralizer grounding
Induction Generators	May be connected and brought up to synchronous speed if it can be demonstrated that the initial voltage drop measured at the PCC is acceptable based on current inrush limits

Source: NYS Standardized Interconnection Requirements and Application Process, NYPSC

2.2.7 24/7 Operation Capability

The project concept envisions solar energy as the microgrid's main generation source. A battery storage system with a total capacity of 12 MWh will considerably enhance the reliability of the microgrid's energy supply, and a 200 kW diesel generator will come online as necessary in island mode. The proposed DERs should be capable of supporting more than seven days of continuous load from the microgrid's core facilities (loads 1, 2, 4, 9, and 10), and may even be able to energize the other facilities at times by bringing the diesel generator on-line. The diesel generator will be equipped with a 1020 gallon tank, which will support around 70 hours of continuous operation.

2.2.8 Two Way Communication with Local Utility

There is currently no automation system in place which would allow communication between the microgrid operator and the existing electrical distribution network in Liberty. The new automation solution proposed in this report will serve as a protocol converter to send and receive all data available to the operator over NYSEG's WAN using industry standard protocols such as DNP3, OPC, Modbus, 61850, and ICCP (IEC 60870-6).

2.2.9 Voltage and Frequency Synchronism When Connected to the Grid

Microgrid controllers will automatically synchronize the frequency and voltage of all DER-generated power, which will include rotating as well as inverter based energy sources. Synchronization is key to maintaining a stable power network. The larger grid also requires constant synchronization of energy sources, but its comparatively higher electrical and mechanical inertia filters out most fast dynamics. In contrast, the microgrid will be quite sensitive to fluctuations in load or generator output. It is therefore crucial to constantly monitor and regulate DER output, especially from the battery storage units, against aggregate load in real time.

2.2.10 Load Following and Frequency and Voltage Stability When Islanded

The microgrid's control scheme in island mode operates quite similar to that of the larger transmission system. The system maintains frequency by controlling discharge from the battery storage units and regulates voltage by controlling reactive power availability. To the degree that flexible loads are available, the MCS can curtail facility load. A new automated isolation switch will allow the MCS to disconnect the supermarket, gas station, public library, and Load Clusters 1-2 in real time.

If generation and discharge matches the load plus the system losses (real and reactive), system frequency and voltage should stay within acceptable limits. Other factors, such as network topology and the distribution of generation and loads, can also affect frequency and voltage stability. The Project Team will consider these factors and develop a microgrid design that accounts for them in the next phase of the NY Prize competition. The comparatively small size of the microgrid introduces new, fast, and dynamics-related problems that will be carefully studied during the engineering design phase.

2.2.11 Diverse Customer Mix

Connected facilities have different effects on power quality and stability based on load size and economic sector. A microgrid with too many industrial and/or digital electronics-based loads may be less reliable because these loads can negatively affect power quality and stability. The Liberty microgrid will connect three municipal facilities, a school, a gas station, a supermarket, and four groups of residential and commercial units. No individual facility will have a significant negative impact on local power quality. The approximate load breakdown by sector for the Liberty microgrid is as follows:[5]

[5] Estimated based on each facility's typical monthly electricity consumption from 2014.

- Liberty Elementary School – 30% of load
- Municipal Facilities – 22% of load
- Supermarket – 24% of load
- Load Clusters 1-4 – 22% of load
- Gas Station – 2% of load

The microgrid is capable of shedding loads that together comprise approximately 49% of aggregate load by consumption (supermarket, gas station, public library, and Load Clusters 1-2).

Together the Liberty Elementary School and Supermarket use around 54% of the microgrid's electricity. Targeted energy efficiency upgrades at these facilities could significantly reduce each facility's (and therefore the microgrid's) average electricity demand (see Section 2.2.14 for more details).

2.2.12 Resiliency to Weather Conditions

The Town of Liberty is exposed to the normal range of weather conditions that affects the Northeastern United States. Extreme weather events include, but are not limited to, torrential rain, snow, and wind that could cause falling objects and debris to disrupt electric service and damage equipment and lives. By implementing line fault notifications and deploying other sensors, microgrid owners can ensure the network is as resilient as possible to storms and other unforeseen forces of nature. At minimum, the new diesel generator will be enclosed inside a container on the school's property. The solar PV will be resilient to all but the most extreme weather conditions, however is cannot be enclosed or containerized to fully protect it.

However, severe weather events will significantly reduce the microgrid's energy generation potential. The Project Team estimates that the solar arrays will produce around 10 MWh during the worst week of the year, but several continuous days of rain or cloudy weather could strain the microgrid's limited energy resources. The inclusion of zinc air batteries in the microgrid design will provide resiliency in that the assets within the footprint will have sufficient capacity to provide electric service to microgrid connected facilities for up to 7 days.

The microgrid's information technology (IT) system is primarily based on wireless communication. Each wireless unit will be housed inside a weather-proof enclosure to ensure resiliency during storms. Each distributed intelligent electronic device (IED) and DER will require a short length of physical wire to connect to the nearest network switch. Network switches will intentionally be placed near the IED or DER that they serve, which makes disruption of a wired connection extremely unlikely. In the event that an IED loses contact with the MCS, it is programmed to act on predetermined set points.

The distribution lines in Liberty will not be buried to provide extra resiliency to storms, wind, and falling trees. The Project Team evaluated the possibility of trenching and burying distribution lines and found the cost to be prohibitively high, and therefore the new lines will be pole mounted. Hardening possibilities for overhead lines include using poles with steel or other reinforced material, though this would come at a significant cost. The switchgear will already be encased and an obstruction free right-of-way for the lines is the only way to protect the wires themselves from damage.

2.2.13 Black Start Capability

The proposed battery storage units and diesel generator will be equipped with black start capabilities. If the Liberty grid unexpectedly loses power, the microgrid control system will initiate island mode by orchestrating the predefined black start sequence. The diesel generator will require an auxiliary source of direct current (DC) power to start multiple times in case of failure.[6] The storage units will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. The MCS will bring the diesel generator on-line and synchronize its output as necessary. After the storage units have established a stable power supply, the MCS will synchronize output from the solar arrays and bring them on-line.

2.2.14 Energy Efficiency Upgrades

EE is critical to the overall microgrid concept. There is significant potential for EE upgrades in Liberty—the Project Team was only able to confirm that the Liberty Central School District is in the design and approval phase of an Energy Performance Contract (EPC) with Johnson Controls. This contract will provide energy savings on heat and electricity, but it is unclear whether any of these upgrades will be installed at the elementary school. Other facilities did not confirm any recent EE upgrades.

The Project Team estimates the reduction potential for the six included facilities and four load groups to be approximately 20 kW. The project will leverage existing NYSEG EE programs to reduce load at existing facilities and will seek to qualify for NYSERDA funded EE programs.

2.2.15 Cyber Security

The Microgrid Management and Control System network data will be fully encrypted when stored or transmitted. Network segmentation by function, network firewalls, and continuous monitoring of data activity will protect the microgrid from cyber intrusion and disruption. Access to the microgrid management and control center will be limited to authorized personnel. Activating and analyzing security logs may provide an additional level of security. The operating system and firewall will be configured to record certain suspicious events such as failed login attempts.

Because the logic controllers (IEDs) will be located at or near loads, the distributed equipment will take the IT system to the "edge" of the network, where it may be more vulnerable to hackers. A practical tool to prevent unauthorized access into the IT network is a program called sticky media access control (MAC). Every network attached device has a media access control MAC interface that is unique to it and will never change. The sticky MAC program will monitor the unique address of the device and its designated network port, and if the device is ever disconnected, the program will disable that port and prevent an unauthorized device from entering the IT system.

[6] This auxiliary DC power battery will likely be a packaged component that DER owners will purchase along with the generator.

2.2.16 Use of Microgrid Logic Controllers

Microprocessor based IEDs serving as microgrid logic controllers are described below in Section 2.7.1. The role of the IED is to provide monitoring and control capabilities of the object being controlled.

2.2.17 Smart Grid Technologies

The microgrid will offer a distributed network architecture allowing smart grid technologies to connect to the grid via multiple protocols including DNP3, OPC, Modbus, 61850, ICCP (IEC 60870-6) and more as required.

2.2.18 Smart Meters

Liberty does not have smart meters installed throughout its coverage area. Smart meters are not required for the Liberty microgrid because the control sequence is performed at the feeder level.

2.2.19 Distribution Automation

The automation solution outlined in this study for Liberty's microgrid includes IEDs that are distributed at or near individual loads. Their role is to control the load and communicate monitored variables to the control system servers for processing, viewing, and data logging. IEDs can operate based on automated signals from the MCS or pre-programmed independent logic (in case of a loss of communication with the MCS).

2.2.20 Energy Storage

The Liberty microgrid includes an energy storage system composed of three zinc air battery units, each rated at 1 MW/4 MWh. The Project Team selected zinc air cell technology because it provides high reliability at a much lower cost than lithium ion or lead acid batteries. Because it is a new technology, zinc air batteries have not accumulated much operational data. However, one manufacturer, Eos Energy Storage, predicts the battery will last 5,000 cycles at greater than 75% efficiency per discharge, and plans to sell the batteries at $160/kilowatt hour (kWh).[7] The MCS will optimize these storage resources for peak shifting, energy arbitrage, and possibly sale of ancillary services to the New York Independent System Operator (NYISO). By "stacking" different uses of energy storage (i.e., microgrid resiliency, frequency regulation, and PV integration), microgrid owners may be able to increase the returns from these expensive units.[8]

2.2.21 Active Network Control System

The MCS will continuously monitor and control the microgrid in both grid-connected and islanded modes. Both monitoring and control will be decomposed into central (slow) and distributed (fast) components. A fast and reliable communication network is needed for such a hierarchical approach to be successful. All controllable components will communicate bi-directionally with the MCS via MODBUS, OPC, DNP3, TCP/IP, or other protocols as required. The communication infrastructure will be based on the site's existing fiber optics backbone partitioned using gigabit Ethernet switches.

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[7] Eos Aurora: http://www.eosenergystorage.com/products/. The Project Team assumed installation will cost an additional 30% of projected capital cost, for a total of $208/kWh.

[8] Lazard's Levelized Cost of Storage Analysis, Version 1.0.

2.2.22 Demand Response

The Liberty microgrid can intentionally switch to island mode to participate in DR programs. However, because entering island mode removes both generation and load off the larger grid, NYSEG may not accept islanded operation as an eligible method of participation. The microgrid's participation in DR programs will therefore likely be limited to curtailing flexible loads and discharging available energy from the battery storage units. These units should reliably have at least 1 MWh of energy available for DR programs,[9] so microgrid owners may be able to bid capacity into the required response programs (CA$HBACK plus). Current prices in the NYISO frequency regulation market are more lucrative, so the microgrid will likely use available capacity for frequency regulation.

2.2.23 Clean Power Sources Integration

The proposed primary energy source—solar energy—will provide the microgrid with zero emission electricity throughout the year. Battery storage systems will enhance the reliability of the energy supply and will allow the microgrid to operate in islanded mode for multiple days. In the future it may be possible to expand the footprint or generation assets to include additional clean power sources. At that time, the Project Team will consider biomass, expanded solar, and expanded battery storage. More detailed methods to capture and convert energy by electric generators or inverters will be explored at a later time.

2.2.24 Optimal Power Flow

The proposed community microgrid has an average load of approximately 231 kW and a peak load of 504 kW. Because of the intermittent nature of solar energy production, NYSEG may negotiate a variable fee for microgrid-produced power. If so, the battery storage units will allow the microgrid to sell power to NYSEG at premium prices and store power when prices are low. However, the Project Team has assumed solar energy will be valued at NYSEG's average local supply price. The solar arrays will most likely not qualify for net metering because the owning SPV does not own a metered facility in the area, and because the arrays greatly exceed the average load of each individual microgrid facility. If possible, the MCS will fully utilize the optimum output of generation sources at the lowest cost in a unique approach that includes maintenance, energy cost, and market prices as part of security constrained optimal power flow (SCOPF).

2.2.25 Storage Optimization

The storage systems will require intelligent controls to work in unison with the microgrid controls. The MCS will fully utilize and optimize the storage resources by managing the charge and discharge of these systems. Possible uses for storage include reducing peak demand, participating in NYISO frequency regulation markets, shifting solar PV output to match aggregate load, and increasing system reliability by providing an energy bank.

[9] 1 MWh is the approximate minimum energy total that will be required to participate in NYSEG's programs.

2.2.26 PV Monitoring, Control, and Forecasting

The microgrid's PV inverters will usually operate at their maximum power point (MPP) because there is no associated O&M cost. In some rare situations, the solar arrays might have to reduce their output to help regulate frequency of local power flow or follow facility electricity demand in island mode. In such situations, the control is almost exclusively local with the output set point communicated by the central controller. As with other renewable energy sources, power output depends on weather and time of day.

The microgrid power management system includes high resolution solar forecasting. Solar forecasting can increase the value of integrated PV and storage systems by intelligently deploying storage to smooth the natural spikes in the daily PV output curve.

2.2.27 Protection Coordination

Microgrid protection strategies can be quite complex depending on the network topology and distribution of load and generation. The existing protection scheme assumes unidirectional power flow of a certain magnitude. The microgrid introduces the possibility of bidirectional power flow in both grid-connected and islanded mode, which may complicate the necessary protection strategy.

2.2.28 Selling Energy and Ancillary Services

It is unclear whether the microgrid will be permitted to back-feed power through Liberty's main substation into the broader NYSEG transmission system. Under the current business model, it is assumed the microgrid will sell energy from the solar arrays to NYSEG. The Project Team has assumed that electricity from the solar arrays will be valued at NYSEG's average local supply price. The battery storage units may allow the microgrid to selectively sell energy at high peak prices.

Most lucrative NYISO ancillary service markets, such as the frequency regulation market, require participants to bid at least 1 MW of capacity. The microgrid's generation assets have an aggregate capacity of 3.87 MW, and average aggregate load in 2014 was 231 kW. Participation in these ancillary service markets is easily possible, but it is important that the storage units maintain a certain level of charge in case of an unpredicted emergency outage. The Project Team expects microgrid owners will bid 1 MW of capacity into the NYISO frequency regulation market. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to relatively small scale generators. However, by selectively selling reserves when prices are high, the battery storage units may make participation in these programs economically viable.

2.2.29 Data Logging Features

The microgrid control center includes a Historian Database to maintain real-time data logs. The Historian Database displays historical trends in system conditions and process variables, and can also be used to predict future events such as system peaks with its built-in statistical analytics tool.

2.2.30 Leverage Private Capital

The microgrid project will seek to leverage private capital where possible in order to develop components of the microgrid. The Project Team is actively developing relationships with investors and project developers that have expressed interest in NY Prize. As the project concept matures, the Project Team will continue to engage these groups to better understand how private capital can be leveraged for this specific project. The Project Team currently envisions sale of energy to NYSEG when the battery storage units have charge available and when prices are competitive. Investors will receive revenue from electricity sales to NYSEG and possibly from participation in ancillary service or DR programs. However, in the current power market this revenue will not be sufficient to recover the project's extreme capital costs without extra incentives or grants. More detail is provided in Section 3.3.3.

2.2.31 Accounting for Needs and Constraints of Stakeholders

Developing the best possible value proposition for the community, utility, local industry, and other community stakeholders is one of this feasibility study's main objectives. The Project Team has engaged with all involved parties to understand their specific needs and constraints. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.2.32 Demonstrate Tangible Community Benefit

The project's success and acceptance rely on its ability to provide benefits to the community. Active participation from the town government, utility, and community groups is crucial to designing a microgrid that meets the community's needs. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the Liberty microgrid design includes a 450 kW solar PV array, a 150 kW solar PV array, a 200 kW diesel backup generator, battery storage consisting of three 1 MW/4 MWh units, and interconnection of the existing 70 kW solar PV array at the elementary school. This section will describe the benefits and costs of the proposed resources and discuss how they will meet the microgrid's objectives in greater detail.

2.3.1 Existing Generation Assets

The Liberty microgrid will incorporate the existing solar PV array at the Elementary School. This asset will stay on-line throughout the year, but electricity output will depend on weather conditions and insolation. In grid-connected mode it will operate as it does currently, providing electricity to the Elementary School and exporting excess energy to the NYSEG grid. In island mode it will contribute charge to the battery units or directly to facilities when necessary. The array will be outfitted with grid paralleling switchgear and controllers to regulate and synchronize its output.

2.3.2 Proposed Generation Assets

The microgrid design includes six new generation assets: a 450 kW carport and ground-mounted solar PV array, a 150 kW roof-mounted solar PV array, a 200 kW diesel backup generator, and three 1 MW/4 MWh battery storage units (shown in Table 3). All of the new DERs will be located at the Liberty Elementary School—the 450 kW solar PV array will be mounted on a carport in the school's parking lot and, if the parking lot is too small, on the field north of the parking lot. The 150 kW solar PV array will be roof-mounted on the west and south wings of the school. Each battery system needs enough space for four 40 foot shipping containers. These batteries could be placed in the field just north of the school's parking lot (as shown in Figure 1), or between the school's parking lot and the school building.

The diesel backup generator will be constructed in an existing utility room at the Liberty Elementary School or placed in an enclosure on the southeast corner of the building. The generator will be Tier IV emissions compliant with approximately 72 hours of on-site fuel storage, and will require approximately 100 square feet of space (23 feet by 4.5 feet) including the storage tank.[10] Diesel was chosen as the backup generation given the greater accessibility and ease of storage of diesel fuel versus propane or other backup power sources. Moreover, diesel generators have the ability to ramp from zero to full capacity almost instantaneously, whereas small gas fired engines do not exhibit comparable ramping speeds. The diesel generators will be Tier 4 certified, with emissions up to 90% less than legacy diesel engines.[11]

Table 3. Proposed Generation Assets

Table shows the rating, fuel, and address for proposed generation assets.

Name	Technology	Rating (kW)	Fuel	Address
DER2	Rooftop-mounted solar PV array	150	Sun Light	201 N. Main St
DER3	Diesel backup generator	200	Diesel	201 N. Main St
DER4	Carport and ground-mounted solar PV array	450	Sun Light	201 N. Main St
DER5	Zinc air battery unit	1 MW/4 MWh	N/A	201 N. Main St
DER6	Zinc air battery unit	1 MW/4 MWh	N/A	201 N. Main St
DER7	Zinc air battery unit	1 MW/4 MWh	N/A	201 N. Main St

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Liberty with multiple additional energy resources. In grid-connected mode, the microgrid's solar arrays will sell electricity to NYSEG at the utility's average supply price. In islanded mode, the solar arrays will charge the battery storage units and export excess energy to connected facilities if the storage units are fully charged. When the solar

[10] Approximate size for 200 kW Generac Industrial Power generator set (SD200).
[11] EPA Tier 4 diesel engine standards: http://www3.epa.gov/otaq/nonroad-diesel.htm.

arrays are not producing electricity, the battery storage units will maintain power flow within the microgrid coverage area.

One of the NYSERDA-defined required microgrid capabilities is to provide continuous power for seven days. The microgrid's average weekly electricity consumption is approximately 39 MWh. By shedding loads, the Liberty microgrid can reduce this weekly consumption to around 20 MWh. Assuming that their charge has been maintained, the battery storage units can provide 12 MWh of electricity over the course of a week. The Project Team estimates the solar arrays can produce approximately 19 MWh per week under normal operating conditions—combined with the battery storage, this level of production would allow the microgrid to power loads 1, 2, 4, 9, and 10 (hereafter referred to as "core loads") for more than seven days.[12] Alternatively, the microgrid could supply power to loads 3, 5, 6, 7, and 8 intermittently throughout the full seven day requirement.

However, many outages are caused by extreme weather events that would also diminish output from the solar PV arrays. The Project Team estimates that during the worst week of a given year, the solar arrays could produce approximately 10 MWh. Combined with the battery storage units, this gives the microgrid around 22 MWh of energy supply. Under these conditions, the microgrid could supply power to core loads for the full seven day requirement. Alternatively, the microgrid could bring the 200 kW diesel generator on-line and energize the non-core loads above switch 8 in Figure 3 throughout the week.

After the battery storage units have been depleted, the MCS will always seek to replenish charge by deploying energy from the solar PV arrays. However, if the solar arrays are not producing sufficient electricity, the 200 kW diesel generator will come on-line and operate continuously until it exhausts its fuel supply, output from the solar arrays increases, or power returns to the larger grid. When aggregate microgrid demand is less than 200 kW, the generator will charge the battery storage units. When aggregate demand exceeds 200 kW, the battery storage units will discharge the necessary power to maintain power flow through the microgrid coverage area.

The proposed assets will be safe from a range of severe weather events. At minimum, the diesel backup generator unit will be constructed inside an enclosure on the Elementary School's campus, where it will be protected from severe weather events. The battery storage units will be similarly enclosed. However, as discussed above, weather may significantly diminish the output from the solar PV arrays.

The microgrid's IT system is primarily based on wireless communication. Each wireless unit will be housed inside a weather-proof enclosure to ensure resiliency during storms. Each distributed IED and DER will require a short length of physical wire to connect to the nearest network switch. Network switches will intentionally be placed near the IED or DER that they serve, which makes disruption of a wired connection extremely unlikely. In the event that an IED loses contact with the MCS, it is programmed to act on predetermined set points.

[12] Estimates of weekly production from solar arrays derived from PV SYST software.

The distribution lines in Liberty will not be buried to provide extra resiliency to storms, wind, and falling trees. The Project Team evaluated the possibility of trenching and burying distribution lines and found the cost to be prohibitively high. Hardening possibilities for overhead lines include using steel or other reinforced material for utility poles, though this would come at a significant cost. The switchgear will already be encased and an obstruction free right-of-way for the lines is the only way to protect the wires themselves from damage.

Because the Liberty microgrid does not include a large spinning generator, the battery storage units must maintain system stability in island mode. The diesel generator may also maintain system stability when it operates. The battery storage units and diesel generator can provide:

- Automatic load following capability – the DERs will be able to respond to frequency fluctuations within cycles, allowing the microgrid to balance demand and supply in island mode.
- Black-start capability – the diesel backup generator will have auxiliary power (batteries) for black starts and can establish island mode grid frequency. After the storage units or diesel generator have established stable power flow, the main microgrid controller will synchronize the solar arrays to match the target frequency and phase and bring them on-line.
- Conformance with New York State Interconnection Standards.[13]

2.4 Load Characterization (Sub Task 2.2)

The Project Team sized proposed DERs according to electricity demand data from Liberty's load points. The load characterizations below describe the electrical loads served by the microgrid.[14] Descriptions of the load sizes to be served by the microgrid along with redundancy opportunities to account for downtime are included.

2.4.1 Electrical Load

The Project Team evaluated six primary electrical loads and four load clusters for the Liberty microgrid. For aggregate weekly, monthly, and yearly energy consumption as well as average and peak power demand, see Table 5. For a typical cumulative 24 hour load profile, see Figure 2. Typical 24-hour load profiles for each facility can be found in the Appendix.

Liberty's proposed community microgrid will incorporate the elementary school, the local police department, several municipal buildings, a gas station, a supermarket, and four groups of residential loads. All included facilities are connected to the primary NYSEG feeder in Liberty (Liberty 145).

[13] New York State Public Service Commission. Standardized Interconnection Requirements and Application Process for New Distributed Generators 2 MW or Less Connected in Parallel with Utility Distribution Systems (2014). Available from *www.dps.ny.gov*.

[14] Estimated loads are based on monthly metering data from the facility's account numbers via NYSEG's on-line metering portal wherever possible. The Project Team simulated load data for the following facilities: the Police Department, the Public Library, the Sun Gate Gas Station, the Great American supermarket, and all four residential load clusters.

Table 4. Town of Liberty List of Prospective Microgrid Facilities

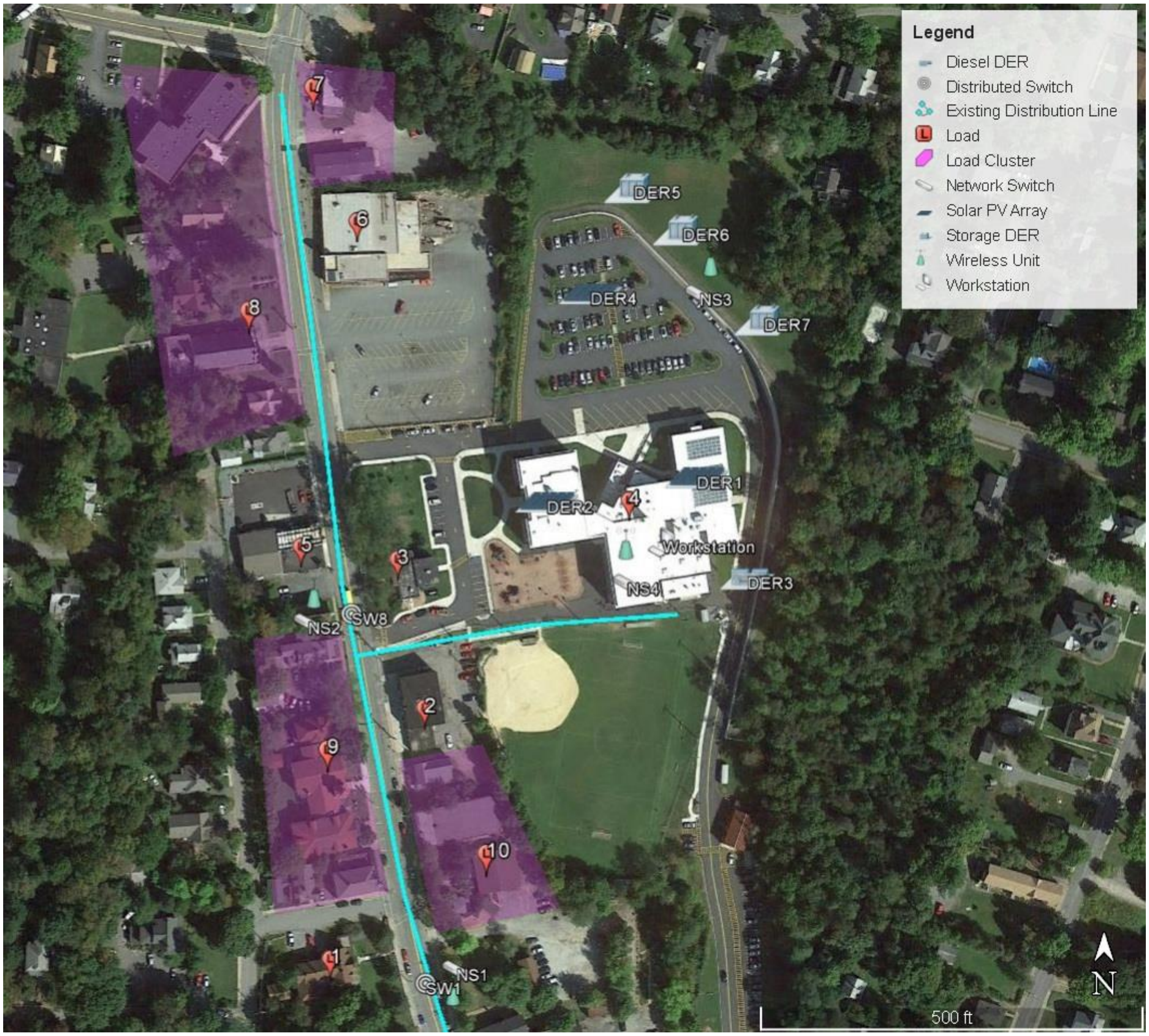
Table lists potential microgrid facilities, including their addresses, and classifications.

	Property	Address	Classification
1	**Town Government Center**	120 N. Main St	Public
2	**Liberty Police Department and Village Office**	159 N. Main St	Public
3	**Liberty Public Library**	189 N. Main St	Public
4	**Liberty Elementary School**	201 N. Main St	School
5	**Sun Gate Mini Mart and Gas Station**	210 N. Main St	Commercial
6	**Great American (Supermarket)**	261 N. Main St	Commercial
7	**Load Cluster 1**	267-275 N. Main St	Residential
8	**Load Cluster 2**	280 S. Main St – 236 N. Main St	Residential
9	**Load Cluster 3**	184 N. Main St – 126 S. Main St	Residential
10	**Load Cluster 4**	159-119 N. Main St	Residential

The design includes two new automated isolation switches and switchgear for every generation asset. The proposed loads are all on the same feeder, so the design does not require construction of new electric distribution lines. Figure 1 provides an illustration of the proposed microgrid design and layout, including loads, switches, existing electrical infrastructure, and proposed electrical infrastructure.

Figure 1. Liberty Equipment Layout

Figure shows the microgrid equipment layout, illustrating distributed energy resources, distribution lines, load points, workstations, network switches, and proposed distribution switches.



NYSEG provided the Project Team with twelve months of metering data for the Liberty Elementary School and the Town Government Center (January through December 2014), summarized in Table 5. The Project Team estimated other facility loads based on facility type, size, and approximate number of customers served. In 2014 the estimated aggregate peak load was 504 kW, and the average was 231 kW.

Because solar PV and battery storage units are the microgrid's main energy source, conserving power in long-term outages is key to maintaining the power supply. The microgrid is capable of shedding loads in island mode. When the microgrid control system determines load shedding is necessary, it will disconnect the Public Library, Sun Gate Gas Station, Great American supermarket, and Load Clusters 1-2 (loads 3, 5, 6, 7, and 8). Table 5 includes cumulative load estimates for full service and post-load shedding scenarios.

Table 5. Liberty's 2014 Microgrid Load Points

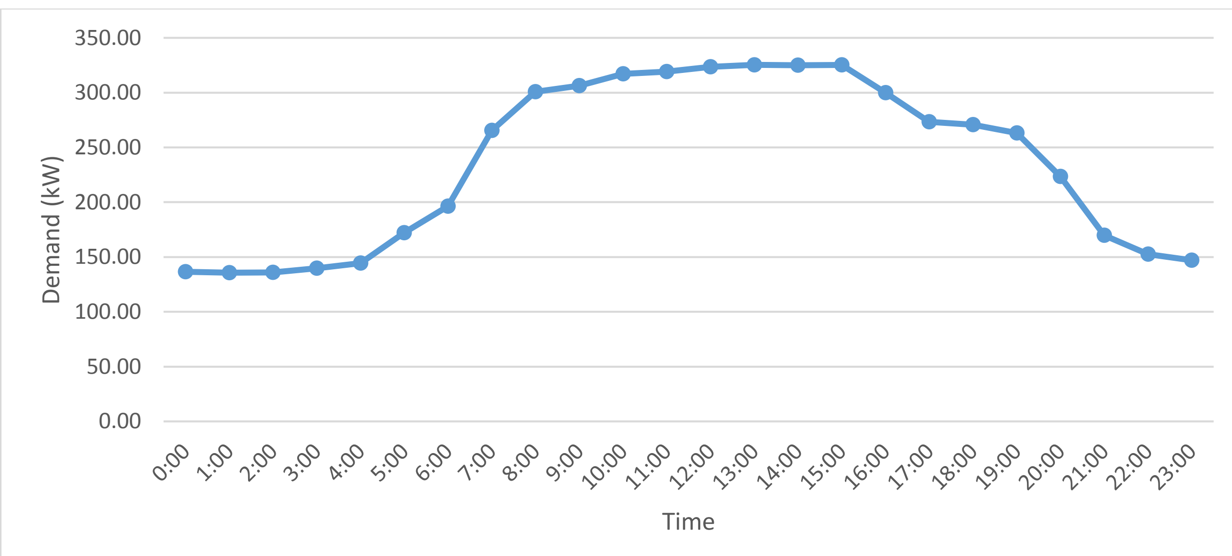
Table shows the microgrid electric demand in kW and electric consumption in kWh for "full microgrid" and "post-load shedding" situations. Thermal consumption was deemed irrelevant because there is no natural gas infrastructure in Liberty.

Scenarios	Electric Demand (kW)		Electric Consumption (kWh)		
	2014 Peak	2014 Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads (Full)	504	231	2,026,268	168,856	39,269
Microgrid Loads (After load shedding)	266	118	1,037,168	86,431	20,100

Figure 2 provides a typical aggregate hourly load profile for Liberty. Aggregate demand begins to increase around dawn, plateaus at around twice the night-time baseline throughout the day, and decreases back to the night-time baseline from 18:00 to 22:00.

Figure 2. Typical 24-Hour Cumulative Load Profile from 2014 Metering Data

Figure illustrates the typical 24-hour cumulative load profile. The figure represents the sum of individual facility typical 24-hour load profiles from 2014.



Although the output of the solar arrays will be variable (due to weather conditions and insolation) throughout the year, they will typically be most productive when facility demand is highest. When the solar arrays are operating close to their name plate capacities, the microgrid's generation capacity will approach 3.87 MW, with 200 kW from the diesel generator, 3 MW from the battery storage units, and 670 kW from the solar PV arrays. Aggregate demand from microgrid facilities averaged 231 kW and never exceeded 504 kW in 2014.[15] The limiting factor on islanded operation will therefore be the total amount of energy stored in batteries rather than the peak discharge rate.

The Project Team expects some degree of natural load growth after construction of the microgrid. Because DERs are sized to approximately match current facility demand, significant load growth could threaten the reliability of the microgrid's electricity supply in island mode. Microgrid facilities can mitigate the threat of natural load growth by investing in EE upgrades or intelligent building energy management systems (BEMS) that respond to commands from the main microgrid controller. This is especially important in the Liberty microgrid project, where there will be a finite supply of energy in islanded mode. Microgrid owners may also invest in additional supply-side resources such as small diesel generators or extra battery storage systems.

Because the design includes three solar arrays, each unit should have downtime available at various points throughout the year; however, the microgrid will need to rely on grid-supplied power and power from the diesel backup generator if the battery storage units are unavailable at any time.

2.4.2 Thermal Consumption

There is currently no natural gas infrastructure in Liberty. Facilities and residential customers use electricity or fuel oil for thermal energy throughout the year. The absence of natural gas precluded the possibility of proposing a CHP unit, so the Project Team did not evaluate thermal consumption for the proposed facilities.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

The existing distribution system infrastructure will be expanded and modified to accommodate microgrid operations. The microgrid will support two fundamental modes of operation: grid-connected (normal or grid paralleling) and islanded (emergency) modes. Details concerning the infrastructure and operations of the proposed microgrid in normal and emergency situations are described below.

2.5.1 Grid Parallel Mode

The microgrid will most often operate in grid-connected mode. In this mode, the proposed solar arrays will sell electricity to NYSEG at the utility's average local supply price. If economic conditions align, the battery storage units may also export energy to the larger grid to participate in ancillary service markets or DR programs. The microgrid design also includes one new diesel backup generator, but this DER will not come on-line in grid-connected mode. Refer to Table ES-2 for a complete list of microgrid DERs.

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[15] This number sums the individual yearly peak demands from connected facilities. It therefore assumes that all facilities reached their peak demands at the same time, which is unlikely. The true peak demand was almost certainly less than 504 kW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

If the larger grid experiences an emergency while the microgrid is connected, the parallel mode control scheme allows for the export of a predetermined amount of active and reactive power from microgrid DERs. By injecting power into the larger grid, the microgrid may be able to balance frequency and voltage to avert an outage.[16] If the battery storage units have sufficient charge to stabilize the larger grid system, they will immediately discharge the required power. However, this discharge should not exceed a certain predetermined amount of power—as the microgrid's main source of energy in island mode, the battery units must always maintain a certain level of charge to prepare for emergencies.

2.5.2 Intentional Islanded Mode

The proposed energy management and control scheme will balance output from the solar arrays and battery discharge with microgrid demand to maintain adequate frequency, voltage, and power flow across the microgrid network in islanded mode. Islanded mode can be intentionally used during forecasted NYSEG grid outages or disturbances to maintain electricity supply for microgrid facilities—the system will manage the solar arrays, battery storage units, and diesel generator to match aggregate demand in real time. The battery storage units can provide real-time response to fluctuations in system frequency and voltage. Refer to the simplified one-line diagram in Figure 3 for a detailed device representation showing both existing and proposed generation assets and their utility interconnection points.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

This section describes the electrical and thermal infrastructure of the proposed microgrid. The infrastructure resiliency, the PCC, and the proposed utility infrastructure investment are also discussed below.

2.6.1 Electrical Infrastructure

The local utility, NYSEG, owns the existing electrical infrastructure in Liberty. The Liberty 145 line is the primary feeder in the area, and is the only feeder that supplies the microgrid coverage area with power. The proposed microgrid is located at the end of the Liberty 145 feeder, meaning that there are no downstream loads. No NYSEG customers will be disconnected when the microgrid operates in islanded mode.

The PCC with the NYSEG system will be located along the Liberty 145 feeder (SW1 in Figure 3). One new automated switch will disconnect the microgrid from this feeder at the PCC. Other isolation switches will provide the microgrid with load shedding capability and control over DERs. The existing manual switch that connects the 70 kW solar array to the larger grid must be upgraded to serve its function in the microgrid control scheme (SW2 in Figure 3).

All of the microgrid's generation assets (including the existing solar array) will require switchgear and controllers to communicate with the microgrid control system. See Figure 1

[16] By averting a larger outage, the microgrid will provide value to the community of Liberty as well as NYSEG. All involved parties therefore have incentive to support such a capability.

(Equipment Layout) for a map of proposed equipment and infrastructure. For a detailed outline of microgrid equipment, see the one-line diagram in Figure 3.

The following tables (Table 6 to Table 8) describe the microgrid components and are referenced throughout the rest of the document.

Table 6. Liberty Distributed Switches Description

Table outlines all distributed electrical switches with their names (on equipment layout), descriptions, and statuses.

Name	Description	New/Upgrade
SW1	Automatic switch for feeder isolation	New
SW2	OEM PV Inverter Switches	Upgrade
SW3	OEM PV Inverter Switches	New
SW4	OEM Diesel Generator Switch	New
SW5	OEM PV Inverter Switches	New
SW6	OEM Storage Inverter Switch	New
SW7	OEM Storage Inverter Switch	New
SW8	Automatic switch for load shedding and microgrid sequence control	New
SW9	OEM Storage Inverter Switch	New

Table 7. Liberty's Network Switch Description

Table outlines all four IT network switches with their descriptions, status as existing or proposed, and addresses.

Name	Description	Status	Address
NS1	Near Switch 1 for communication	Proposed	Refer to Eqp. Layout
NS2	Near Switch 8 for communication	Proposed	Refer to Eqp. Layout
NS3	Near DER 4-7 for communication	Proposed	201 N. Main St
NS4	Near DER 1-3, EMS, and workstations for communication	Proposed	201 N. Main St

Table 8. Liberty's Server Description

Table describes the workstation and servers, their status as proposed, and their addresses. The Project Team has assumed that the servers will be placed inside the Liberty Elementary School.

Name	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	201 N. Main St
Server1	Primary EMS and Supervisory Control and Data Acquisition (SCADA)	Proposed	201 N. Main St
Server2	Secondary EMS and SCADA	Proposed	201 N. Main St

The NYSEG distribution system in Liberty consists of medium voltage lines (4.8 kV). All branches off these medium voltage lines have their own transformers that step incoming power down to low voltage.

Figure 3. Liberty One-Line Diagram

Figure displays a one-line diagram for Liberty illustrating interconnections and lay-out.

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2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed components and interconnection points for the Liberty community microgrid are listed in Table 9. The PCC between the main grid and the microgrid will be located along the NYSEG Liberty 145 feeder (SW1 in Figure 3). New automated circuit breakers and switches will be required to isolate the microgrid loads from the local NYSEG feeder and to segment loads during islanded operation.

The microgrid includes one new automated isolation switch that will disconnect noncritical loads 3, 5, 6, 7, and 8 (see Figure 3). Load shedding capability will help the MCS maintain system stability and conserve energy in island mode. This capability will be especially valuable in long-term outage situations.

The MCS will also have precise control over the discharge rate of battery storage units and the output from the diesel backup generator. The battery storage units' immediate discharge capability will allow the MCS to provide voltage and frequency control within the millisecond response intervals required for maintaining a stable microgrid.

Table 3. List of Components

Table lists all the distribution devices/components included in the microgrid design.

Device	Quantity	Purpose/Functionality
Microgrid Control System Protocol Converter (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	Protocol Converter responsible for operating the microgrid's field devices via protocol IEC-61850.
Automated, Pole-mounted Circuit Breaker/Switches (Siemens 7SC80 relay or equivalent)	2	New relays/controllers at pole mounted distribution switches/breakers. These components will disconnect the microgrid from the Liberty 145 feeder and can shed loads 3, 5, 6, 7, and 8. Components include synchro-check capability.
Generation Controls (OEM CAT, Cummins, etc.)	1	OEM Generation controllers serve as the primary resource for coordinating diesel generator ramp up/ramp down based on external commands and reaction to Microgrid load changes
PV Inverter Controller (OEM Fronius or equivalent)	3	These components control PV output and send live solar/power output data to SCADA and EMS for forecasting/decision making input
Storage Inverter Controller (OEM Fronius or equivalent)	3	These components control battery storage input/output and send live power data to SCADA and EMS for forecasting. They receive charge/discharge commands from SCADA Microgrid control.
Network Switch (RuggedCom or equivalent)	4	These IT components are located at or near IEDs and controllers for network connection, allowing remote monitoring and control.

All microgrid devices will require a reliable source of DC power. Each device (or cluster of devices) will have a primary and backup power supply source. During normal operation, a 120 volt alternating current (VAC) power source will power an alternating current (AC)/DC converter to power the microgrid devices and maintain the charge of the DC battery banks. The device current draw (amperage used by each device) should not exceed 60% of the available power supply. When the normal AC voltage source is unavailable, the battery bank can provide DC power to devices for at least one week.

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

The power system protection system senses grid variables, including voltage, current, and frequency, and takes necessary actions (such as de-energizing a circuit line) to maintain these variables at appropriate levels. Currently, protection schemes are based on the assumption that power flows in one direction. Microgrid operations, particularly during island mode, require bidirectional power flow. This will introduce difficulties for protection coordination. At a later design stage, protection studies accounting for the key characteristics of island mode will have to be performed, which include possible bidirectional power flows and very low fault currents.

The current design includes controls that can prevent back-feeding of power to the larger NYSEG grid. However, the business model assumes the microgrid will export energy back to NYSEG.

2.6.4 Thermal Infrastructure

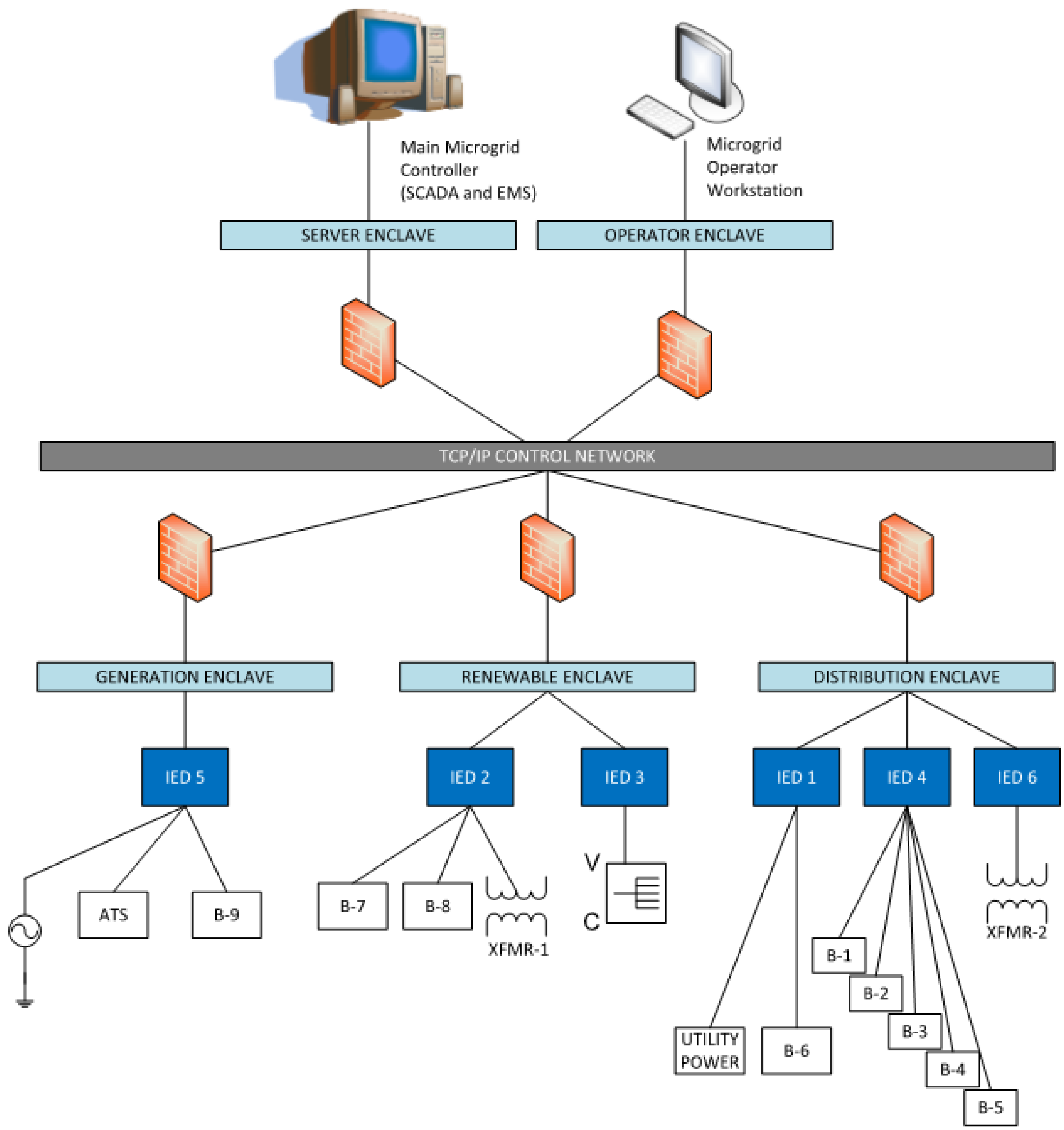
There is no natural gas infrastructure in Liberty. Facilities and residential customers use electricity or fuel oil for thermal energy throughout the year.

2.7 Microgrid and Building Control Characterization (Sub Task 2.5)

This section provides a more detailed description of the microgrid's modes of operation. The microgrid control system will include an EMS and a SCADA based control center (see Figure 4), hereafter collectively referred to as the main microgrid controller. Distributed IEDs will communicate with the main microgrid controller over the local Transmission Control Protocol/Internet Protocol (TCP/IP) network. In grid-parallel mode, the microgrid will synchronize frequency and voltage magnitude with the larger grid and will have the potential to export excess electricity to NYSEG. When controllers detect an outage or emergency disturbance on the larger grid, the microgrid will switch to island mode. In these situations, the microgrid will disconnect from the larger grid and proceed with the programmed black-start sequence (described in Section 2.7.6) to start power flow through included lines and devices. When power returns after an outage, the main microgrid controller will manage re-synchronization to the NYSEG grid (described in Section 2.7.7).

Figure 4. Diagram of Representative Microgrid Control System Hierarchy

The following network diagram illustrates a conceptual microgrid control network with a generator, breakers, transformers, an automatic transfer switch (ATS), IEDs (which could be actuators, Meters, Accumulators, or Programmable Logic Controller (PLCs)), a renewable energy source, and the Main Microgrid Controller with SCADA and Energy Management System (EMS) server and client workstation node.



2.7.1 Microgrid Supporting Computer Hardware, Software, and Control Components

The following is a preliminary list of hardware components needed for Liberty's microgrid:

- Energy sources – The microgrid requires DERs in order to supply electricity to connected facilities. To some degree, flexible loads that can be reduced during peak demand events may also be considered as energy sources.
- Microgrid Control System – The MCS is composed of an Energy Management System (EMS) and SCADA based control center. The MCS is responsible for logging relevant data, regulating generator output, curtailing flexible loads (where possible), and managing transitions between modes of operation.
- Distribution system – The microgrid requires automated switches and breakers to isolate the microgrid from the local feeder and disconnect downstream loads. Other control elements at or near individual loads will allow the MCS to maintain adequate power stability in islanded mode.
- Utility breakers and controls – These automatic controls will interface between the microgrid and the main NYSEG feeder (Liberty 145).
- Generator controls/relays – These components will be installed at each generating unit/inverter. They will control generator output based on signals from the MCS.

The proposed system uses Service Oriented Architecture (SOA) software that serves as the messaging and integration platform for the monitoring and control of distributed equipment. The SOA is vendor-agnostic—it supports almost any power device or control system from any major vendor—and therefore ensures communication networkability and interoperability between competing vendor systems. The computer hardware and software required for a fully automated operational microgrid design are:

- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- Two Redundant Array of Independent Disks (RAID) 5 servers (including 1 primary, 1 backup) for the MCS – The MCS will include an EMS and a SCADA based control center, and will optimize the operation of the microgrid. This includes determining which loads will be supplied, integrating PV output into the energy portfolio (including high resolution solar forecasting), and controlling the charge/discharge of energy storage units. The system combines information on power quality, utilization, and capacity in real time, which allows the community and control algorithms to balance electricity supply with microgrid demand.
- Historian database server – Historian database collects and logs data from various devices on the network.
- Application servers (one or more) – Depending on the software and hardware vendors' preference, application servers may be used for numerous purposes. Common uses for an application server include (but are not limited to) backup and recovery, antivirus, security

updates, databases, a web server, or use as some other software (depending on how the SCADA and EMS vendors configure their platform).

- Operator workstations for SCADA and EMS – Workstation computers, sometimes called thin-clients, allow operators to view real-time data and control the microgrid from the SCADA control room or a remote location. Users must have proper access rights and permissions to operate workstation computers.
- Intelligent Electronic Device Distribution Switches: Automated pole mount circuit breaker/switch (Siemens 7SC80 relay) – The microprocessor based logic controllers, also referred to as IEDs, are located at or near loads and are programmed to act on predetermined set points. They can also be manually overridden by the MCS or a human operator. The control system host servers continuously poll these logic controllers for data using discrete or analog signals. Resulting data is processed by the IEDs connected to control elements.
- PV Inverter Controller (OEM Fronius, etc.) – These components will control output from the solar PV arrays and send data to the MCS for forecasting.
- Storage Inverter Controller (OEM Fronius, etc.) – These components will control output from the battery storage units and convert DC to alternating current (AC) power before it reaches the microgrid.

Use of the listed hardware, software, and resources must be synchronized to maintain stable and reliable operation and achieve maximum benefits.

2.7.2 Grid Parallel Mode Control

When the microgrid operates in grid-connected mode, every on-line DER will synchronize its voltage (magnitude and angle) and frequency with the voltage (magnitude and phase) and frequency of the electrically closest interconnection point with the main grid. After initial synchronization, the DER voltage phase will drift away from the main grid's voltage phase, which will allow the flow of active and reactive power. The DER's voltage magnitude and frequency will be maintained as close as possible to the main grid's voltage magnitude and frequency. During grid parallel mode, generation assets will follow the Institute of Electrical and Electronics Engineers (IEEE) 1547 standard for interconnecting distributed resources with electric power systems. The IEEE 1547 and other DER interconnection standards required by utilities are applicable to synchronous, asynchronous, and inverter-based generation.

A utility might have additional technical and economic requirements if the microgrid plans to export energy or provide ancillary services to the distribution grid. The proposed battery storage is capable of providing ancillary services to the NYSEG grid to enhance the reliability of the system. These services can include frequency regulation, spin/non-spin reserve, and voltage support. The microgrid control system may also use batteries for energy arbitrage, or purchasing electricity from the larger grid at low prices and selling it back at a higher price when demand is highest.

2.7.3 Energy Management in Grid Parallel Mode

The proposed microgrid will integrate software and hardware systems to ensure reliability and effective performance. Optimization of microgrid performance involves three distinct phases: measurement and decision, scheduling and optimization, and finally execution and real time optimization.

Data logging features will allow the main microgrid controller to measure historical performance and track significant trends. Human operators can use this data to prioritize loads, manage generator output, and schedule maintenance for generators and microgrid components. The microgrid executive dashboard will collect and filter information on the current operating strategy as well as performance metrics for SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index), all adjusted to reflect the high sampling frequency of the system. Other performance metrics include power interruptions (defined as 50% variance of predicted voltage to measured voltage for 10 minutes or longer), voltage violation (defined as variance of actual voltage to predicted voltage for 5 minutes), and frequency violations (defined as variation to predicted frequency of more than 0.2 hertz for more than 10 minutes). The executive dashboard will calculate daily, weekly, and monthly rolling totals for all of these metrics.

After analyzing historical trends and monitoring real-time data, the main microgrid controller will optimize operation of the microgrid by managing battery discharge and flexible loads. In grid-connected mode the MCS will prioritize the deployment of renewable generation and will aim to offset electrical demand charges whenever possible.

2.7.4 Islanded Mode Control

The transition to island mode can be either unintentional or intentional. Unintentional islanding is essentially the main microgrid controller's programmed response to an outage at the level of the distribution or transmission system. An outage at the distribution system level can occur within or outside the microgrid, and the microgrid islanding scheme must be able to handle either situation. MCS relays at the PCC will recognize low voltage, and the appropriate switch will open automatically, disconnecting the microgrid from the larger grid. Any existing on-line generation will be disconnected via generation breakers. All microgrid loads and distribution switches will then be switched open via designated circuit breakers and relays to prepare for local generation startup. Using the battery storage units' black-start capabilities, the MCS will commence island mode operation.[17] If battery storage units are unavailable or have exhausted their charge, the diesel generator can initiate power flow through the microgrid. The battery storage unit or diesel generator will ramp up to 60 hertz (Hz) and prepare to supply each of the microgrid loads in sequence. After power flow through the microgrid is stable, the main microgrid controller will synchronize output from the solar arrays (voltage and frequency) and

[17] Battery storage units can reliably perform black starts if they have sufficient charge. See http://www.irena.org/DocumentDownloads/Publications/IRENA_Battery_Storage_case_studies_2015.pdf.

bring them on-line. In steady state, their phases will be different, just as they are during grid-connected steady state operation.

Unlike the unintentional transition to island mode, the intentional transition is seamless and closed (it does not require a black start). The microgrid will intentionally switch to island mode if:

- The NYSEG grid has an expected outage that could potentially affect transmission power to Liberty substations.
- The NYSEG grid needs to perform network maintenance work, thereby isolating loads in the Liberty area.

The intentional transition to island mode begins when the system operator sends the command to prepare for islanding. The main microgrid controller will automatically parallel the generation assets. The battery storage units or the diesel generator may set the system frequency. Once the available power sources are synchronized, the system is considered ready to implement islanded operation and will open the incoming utility line breaker.

2.7.5 Energy Management in Islanded Mode

After completing the transition to island mode, the main microgrid controller will perform a series of operational tests to ensure the microgrid is operating as expected and that power flow is stable and reliable. The MCS will gather data on power flow, short circuit, voltage stability, and power system optimization using an N+1 (N components plus at least one independent backup component) contingency strategy to determine whether additional load can be added.[18] The N+1 strategy ensures extra generation is always online to handle the loss of the largest DER and assumes the on-line DER with the highest capacity could go off line unexpectedly at any time. It should be noted that low-priority loads may be disconnected in order to maintain the N+1 power assurance.

The microgrid must also be capable of handling any contingencies that may occur within the islanded system. These contingencies include, but are not limited to:

- Battery storage units exhaust available charge.
- Storage units or PV arrays trip off unexpectedly during microgrid operation.
- Switchgear fails to operate.
- Switchgear fails to report status.
- Loss of power from the diesel generator.
- Loss of power from the solar arrays.

The MCS will optimize the microgrid's operation by managing generation assets and prioritizing loads according to operational requirements. Proposed DERs will provide stable, sustainable, and

[18] The microgrid control system only truly has control over Loads 3, 5, 6, 7, and 8 as one unit in the current design, but by installing intelligent Building Energy Management Systems or additional isolated switches, future operators of the microgrid can enhance load shedding and flexible load control capabilities.

reliable power. The MCS will continuously balance generation and load in real-time, monitoring relevant variables (i.e., system frequency and voltage) and adjusting DER output as necessary. The main microgrid controller will first deploy energy from renewable generation assets and adjust output from the battery storage units to match remaining electricity demand. In the event that the battery storage units exhaust their charge in island mode, the diesel generator will come on-line as necessary. The microgrid design relies on the battery storage units to firm the output from the solar arrays.

The proposed battery storage can be used for multiple purposes:

- Long-term storage: Long-term backup, to be used in conjunction with solar PV arrays and diesel generators to maintain power in a long-term outage.
- Ancillary services: Frequency regulation (enhances stability by providing an immediate response to a change in system frequency), spin/non-spin reserves (providing capacity to the NYISO), and voltage support (ensure reliable and continuous electricity flow across the grid).
- Shifting solar output: Storing excess generation from the solar PV arrays for a few hours, usually to offset higher priced periods (e.g., shifting excess solar generation from 1-3 PM to 4-6 PM when grids tend to peak).
- Energy arbitrage: Similar to shifting solar output, but instead of storing excess generation from the solar arrays, the microgrid will purchase wholesale electricity from the NYISO when the Location-Based Marginal Price (LBMP) is low and sell it back to the NYISO when the LBMP is high.
- Black starts: The units can start power flow through the microgrid in the event of an unplanned larger grid outage.

2.7.6 Black Start

The proposed battery storage units and diesel generator will be equipped with black start capabilities. If the Liberty grid unexpectedly loses power, the main microgrid controller will initiate island mode by orchestrating the predefined black start sequence. The microgrid then begins the unintentional transition to island mode. A DC auxiliary support system is an essential part of the diesel generator's black start capabilities. The battery system must have enough power to start the generator multiple times in case it fails to start the first time.

When the larger grid unexpectedly loses power, the main microgrid controller orchestrates the black start sequence as follows:

1. PCC breaker opens.
2. All active DERs are disconnected.
3. The main microgrid controller waits a pre-set amount of time (approximately 30 seconds) in case power returns to the NYSEG grid.
4. The main microgrid controller disconnects the entire current load (after estimating aggregate electricity demand).

5. The microgrid DERs are synchronized with each other (one of the battery storage units will usually provide reference voltage and frequency).
6. The main microgrid controller reconnects the microgrid loads based on the available generation and a predetermined load priority order.

The MCS will manage any contingencies that arise during the black-start operation (e.g., breakers do not respond to trip commands and the microgrid does not properly disconnect from the larger grid). If one of the battery storage units malfunctions or the diesel generator does not start as expected during a utility outage, the MCS is equipped with contingency algorithms to appropriately manage the situation. If possible, the main microgrid controller will still isolate the microgrid, but only core loads will be satisfied.

The MCS will allow operators to designate certain DERs as unavailable for participation in the microgrid (e.g., if they require maintenance) so the DER dispatch and load shedding algorithms can accommodate a reduced available capacity.

2.7.7 Resynchronization to NYSEG Power

When power is restored to the larger grid, the main microgrid controller will coordinate a safe and orderly re-connection. The system will first wait a predefined, configurable time period to ensure that power has been reliably restored and then will commence resynchronization with the NYSEG power supply. As a final check, the system operator will either receive an automated notification or directly contact NYSEG to confirm that power flow on the larger grid is on-line and stable.

While operating in island mode, the system will constantly monitor the status of the utility feeder at the PCC and determine when appropriate levels of current and voltage have been restored. When power is restored, the main microgrid controller will disconnect the solar arrays and synchronize output from the battery storage units with the utility service through the utility circuit breaker. Before the microgrid system starts paralleling with the utility, it will balance local generation and load so as not to exceed either minimum or maximum export limits or time durations set forth in the utility interconnection agreement. When microgrid power flow has been synchronized to the larger grid, the main microgrid controller will bring the solar arrays back on-line and stop discharge from the battery storage units. Depending on available charge, the batteries may need to charge for a significant period of time after re-connection to the larger grid.

Please refer to the Liberty Microgrid Operation One-Line: Parallel Mode (from Islanded Mode) in the Appendix for the control scheme sequence of operations.

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

The existing information technology and telecommunication infrastructure at Liberty is best suited for a wireless microgrid communication system. The communication system and network switches (which have local backup batteries) will communicate wirelessly with the base station located at the Liberty Elementary School, which is electrically served by the microgrid in islanded mode. During the intermittent stage, or black start sequence mode, the headend IT network equipment and base station for the IT network communications system will be powered by their backup batteries. The microgrid design will require minimal additional hardware (i.e., the network switches, WiMax Base Station, WiMax subscriber units, servers, and computers required to manage a microgrid) to seamlessly integrate with the IT system.

2.8.1 Existing IT & Telecommunications Infrastructure

Liberty already takes advantage of its existing fiber optic backbone ring and existing Ethernet switches for reliable Internet and Local Area Network (LAN) activities, making convergence quite feasible. The wireless components of the control system, which work on open architecture protocols, use a TCP/IP Ethernet-enabled component that controls each of the uniquely addressed modules to wirelessly communicate via a standard, non-licensed radio frequency mesh 900 megahertz (MHz) industrial scientific and medical (ISM) band signal network.

2.8.2 IT Infrastructure and Microgrid Integration

New hardware and software will be required to ensure compatibility between the existing IT infrastructure and proposed microgrid system. There are seven main components required for any microgrid system to successfully integrate with an IT/telecommunication infrastructure: host servers, application servers, operator workstations, network switches, network-attached logic controllers, data transmission systems (either fiber or Ethernet cables), and the vendor agnostic SOA software that facilitates the monitoring and control of virtually any power device or control system. All of these critical parts work together and serve a specific role.

2.8.3 Network Resiliency

Cyber security falls into the two primary stages (1) design and planning, and (2) continuous operations. Cyber security is especially important for the microgrid control system as it utilizes TCP/IP protocols for compatibility amongst the distribution system. This convergence has also introduced vulnerabilities to the MCS because the MCS vendors have historically lagged behind in implementing security patches rolled out by Windows, or PC-based security teams.

For the planning stage, design considerations address cyber security by assigning roles to network-attached components on NYSEG’s WAN thereby controlling data flow and access permissions over the integrated MCS and overarching IT architecture.[19] For example, the design utilizes a network segmentation scheme by function (separate segments/enclaves for servers, operators, generation, and distribution), in addition to network firewalls, for clean and continuous monitoring and control of data flow. The firewall routes noncritical traffic such as utility’s unrelated corporate printers and other drivers, email, and all other non-essential internet services (which could be backdoors for hackers into the MCS) to a dedicated “demilitarized zone” usually consisting of a single security hardened server.

Because the logic controllers will be located at or near loads, the distributed equipment will take the IT system to the “edge” of NYSEG’s network, where it is potentially more vulnerable to

[19] Assumes the microgrid will utilize enterprise-level remote monitoring and control.

hackers. Sticky media access control (MAC) is an inexpensive and practical program that can help prevent unauthorized access and protect the NYSEG IT network. Every network attached device has a unique, unchanging MAC interface. The Sticky MAC program is configured to monitor the unique address of the device and its designated network port. If the device disconnects, the program disables the port and thus prevents an unauthorized device that may have malicious code from entering the IT system.[20]

Physical security measures, such as electronic badge access or cipher combination hardware locksets, should also be considered. The Project Team recommends implementing physical security at the perimeter of the control center building and network communication closets where the switches reside.

The data transmitted throughout the proposed Liberty microgrid will be encrypted, but several additional intrusion protection measures can easily be implemented. One simple and inexpensive method is to disable any of the 65,535 TCP ports not used to make the microgrid system work (depending on final configuration, only a few TCP ports will need to be active). More TCP ports will need to be active when the available enterprise-level monitoring and control access will be utilized.

Activating and analyzing security logs is also important. As a rule, the operating system and firewall can be configured so certain events (e.g., failed login attempts) are recorded. The security portion (software that resides on the control system servers) will be configured so only operators and engineers with specific login credentials can access and control the microgrid.

In the event of a loss of communication with the IT system, the microgrid will continue to operate. The programmed logic code for the network attached controllers is stored locally in each module, giving the controllers the ability to operate as standalone computers in the event of a disruption between the IT system and microgrid.

The Team considers the safety and availability of the microgrid to be the most critical aspects of the microgrid. Testing and/or simulation of the system responses to software updates is important because it allows the owner or operator to identify any anomalies which the software updates might introduce to the overall system before full deployment in the field. Further considerations will be assessed during the next phase of the Prize initiative.

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

After thorough examination of existing utility infrastructure and energy demand requirements, the Project Team has provided a reliable microgrid design. Control components will efficiently manage the real-time operation of the microgrid by communicating with distributed IEDs. The proposed design is resilient to forces of nature and cyber threats and offers full automation and

[20] Sticky MAC is a common, widely effective IT security countermeasure. The Project Team does not foresee any difficulties integrating Sticky MAC into microgrid operations.

scalability at every level. The SOA-based framework ensures interoperability and compatibility between components, regardless of final vendor.

In conclusion, the project is technically feasible. However, two significant items remain in order for Liberty's microgrid to become a reality. First, generation assets and microgrid components must be available for maintenance at all times. The team is working with the Liberty Elementary School to ensure they will allow a third party to service the generation assets and microgrid components located on their land. The Project Team expects these operational challenges to be resolved by the time of construction. Second, there is no natural gas infrastructure in Liberty, which will make it difficult to meet the NYSERDA-defined required capability of providing continuous power for seven days. The design proposes large scale battery storage units that will work with solar PV arrays in order to meet this capability. However, the high cost of battery storage units prevented a microgrid design wherein 100% of islanded energy comes from solar energy and battery storage—the design therefore includes a small diesel generator that will come on-line in long-term outages when the solar PV arrays are not producing power.

The microgrid design proposes upgrades to one existing manual switch and installation of seven new automated switches. The design does not require additional cabling to connect separated facilities. Because the coverage area is located on the end of the Liberty 145 feeder, the microgrid can intentionally enter islanded mode without disconnecting downstream loads.

3. Assessment of Microgrid's Commercial and Financial Feasibility (Task 3)

The microgrid design relies on the SPV to finance the construction of proposed DERs, while NYSEG may construct the required microgrid infrastructure components. The battery storage system should participate in ancillary service markets or DR programs in order to partially recover their high capital costs. However, after bidding 1 MW of capacity into the NYISO frequency regulation market and selling solar-generated power to NYSEG, the project's revenues are still insufficient to cover operating expenses and will not recover initial capital expenditures. NY Prize funding and additional subsidies will be necessary to make the Liberty microgrid financially viable.

3.1 Commercial Viability – Customers (Sub Task 3.1)

Private investors, through the SPV, will own the proposed DERs and NYSEG may own the microgrid components. The solar arrays will stay on-line throughout the year, but their output will be intermittent.[21] Electricity generated by the solar arrays will be valued at NYSEG's supply charge. The battery storage units can bid 1 MW of capacity into the NYISO frequency regulation market and may be able to gain additional savings by engaging in time-of-use (TOU) bill management and reducing peak demand charges. Batteries also provide non-cash values, such as deferral of transmission and distribution (T&D) infrastructure upgrades and reduction of congestion costs, to the utility and larger electricity system. Liberty, specifically is a NYSEG identified load pocket in need of additional DERs to help address congestion. By compensating SPV investors appropriately for these non-cash values, NYSEG and New York State have the capability to make the Liberty microgrid a more attractive investment. Finally, DER owners will remit payment to NYSEG to support the costs of the control infrastructure.

3.1.1 Microgrid Customers

Although it is possible for the microgrid to sell power directly to the facilities, the current business model assumes the microgrid will sell solar power and potentially stored power to the NYSEG grid. As a result, the customers will continue to purchase electricity from NYSEG throughout the vast majority of the year. However, when there is an outage on the larger NYSEG system, the microgrid will switch to island mode and customers will receive electricity directly from the microgrid SPV via NYSEG infrastructure. The transition to islanded operation may be intentional or unintentional.

Although facilities outside the microgrid's footprint will not receive electricity from the microgrid's generation assets during emergency outages, they will benefit from the availability of critical and important services. In their day-to-day operations, each of the microgrid facilities serves the larger community. By providing critical services to the community, these facilities extend their reach beyond direct employees and residents in the event of emergencies.

Table 10 (below) identifies each of the direct microgrid customers. The full group of stakeholders that will benefit from the microgrid is discussed in Section 3.2.3.

[21] The Project Team calculated a capacity factor of 14% using NREL PV Watts software.

Table 10. Microgrid Customers

Facilities that will be connected to the microgrid. All will purchase electricity from the microgrid in island mode, and will indirectly purchase electricity from the microgrid's DERs in grid-connected mode. Although the Liberty Elementary School owns a 70 kW solar array, the Project Team did not consider this generation asset a "back-up generator" because of its intermittent output.

Property	Address	Classification	Critical Service	Back-up Generation
Town Government Center	120 N. Main St	Public	Yes	No
Liberty Police Department and Village Office	159 N. Main St	Public	Yes	No
Liberty Public Library	189 N. Main St	Public	Yes	No
Liberty Elementary School	201 N. Main St	School	Yes	No
Sun Gate Mini Mart and Gas Station	210 N. Main St	Commercial	Yes	No
Great American (Supermarket)	261 N. Main St	Commercial	Yes	No
Load Cluster 1	267-275 N. Main St	Residential/ Commercial	No	No
Load Cluster 2	280 S. Main St – 236 N. Main St	Residential/ Commercial	No	No
Load Cluster 3	184 N. Main St – 126 S. Main St	Residential/ Commercial	No	No
Load Cluster 4	159-119 N. Main St	Residential/ Commercial	No	No

3.1.2 Benefits and Costs to Other Stakeholders

Stakeholders in the Liberty microgrid extend beyond connected facilities to include SPV investors, existing generation asset owners, NYSEG, and residents of Liberty and the surrounding communities.

The majority of benefits and costs to other stakeholders fall into the following categories:

- Supply of power during emergency outages
- Electricity generation in grid-connected mode
- Provision of ancillary services in grid-connected mode
- Cash Flows to owners from electricity and ancillary service sales
- Upfront capital investment and land requirements
- Expanded zero-emission energy generation

Details of each will be discussed in turn below.

Supply of power during emergency outages: The microgrid will supply power to six critical facilities as well as four residential and commercial load clusters. The critical facilities can provide shelter, law enforcement, emergency services, and groceries to residents of the Town in the event of a long-term grid outage.

Electricity generation in grid-connected mode: The solar PV arrays will stay on-line throughout the year. Integration with battery storage will reduce load for the larger NYSEG system during both peak demand events and normal periods of operation, stabilizing electricity prices in the area and possibly deferring the utility's future capacity investments. As Liberty is considered a congestion point on the larger NYSEG and NYISO systems, peak load support from proposed generation assets will reduce congestion costs to NYISO, NYSEG, and their electricity customers.

Provision of ancillary services in grid-connected mode: The battery storage system will bid 1 MW of capacity into the NYISO frequency regulation market throughout the year. By continuously discharging or charging according to signals from the NYISO, the batteries will produce revenues for SPV owners and improve power stability on the larger grid.

Cash flows to DER owners: In a conservative base case, cash flows will be limited to energy sales to NYSEG and sale of ancillary services to the NYISO. The microgrid project will produce consistently negative operating cash flows unless battery storage units can engage in local time of use (TOU) bill management and peak demand reduction or are compensated for non-cash values by the utility or state. The project's commercial viability will likely depend on NYSERDA NY Prize Phase III funding as well as additional subsides.

Upfront capital investment and land requirements: The primary costs will be purchasing and installing necessary microgrid equipment and proposed generation assets. The Liberty Elementary School has land available for the proposed DERs, but the solar arrays will prevent any alternative future use of the land and roof space.

Expanded zero-emission energy generation: The proposed solar arrays will produce zero emission electricity throughout the year. They represent a significant local investment in renewable energy and will reduce greenhouse gas emissions in New York State. This provides benefits to residents of Liberty, the local government, and the larger population of the state. The proposed diesel generator will only come online in island mode when the battery units have exhausted their charges.

3.1.3 Purchasing Relationship

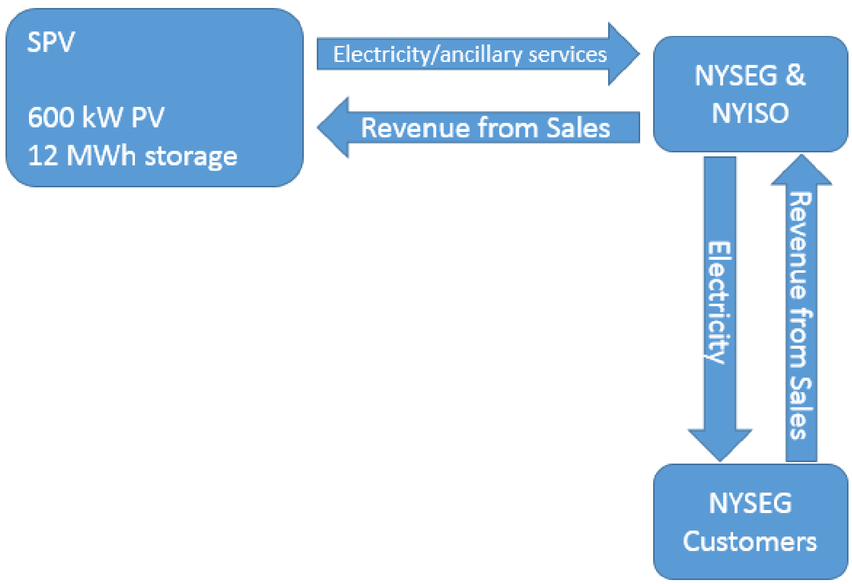
In grid-connected mode, the SPV will sell electricity from the proposed solar PV arrays to NYSEG under a long-term power purchase agreement (PPA).[22] The battery storage units may be used to smooth the output curve from the various solar arrays. Microgrid connected facilities will maintain their current electricity-purchaser relationship with NYSEG during grid-connected mode. In island mode, however, the facilities will be physically disconnected from the larger grid and directly supplied by the proposed generation assets. NYSEG will continue to bill customers for energy usage and pay the SPV for electricity supplied by the DERs under the established long-term PPA. Islanded operation contracts will be established during development and construction and will address the order in which islanded facilities are brought back on-line

[22] The proposed solar arrays will not qualify for net metering because they will be owned by the SPV, which does not own a metered facility in the area.

following an island event and the associated cost for participating in the microgrid. See Figure 5 below for the purchasing relationships.

Figure 5. Purchasing Relationship

Value streams and purchasing relationships between the various entities during both grid-connected and island mode. In island mode the 200 kW diesel generator may also come online to provide electricity to microgrid facilities.



3.1.4 Solicitation and Registration

The microgrid design team will work with the Town and utility to formalize agreements with the critical facilities identified. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid and fee structure determined by the NYPSC. Formal registration with the microgrid will be managed by programming the logic controllers to include or exclude facilities from islanded services based on their agreements with the utility. The Project Team views registration as an operational feature and not a legal requirement.

3.1.5 Energy Commodities

The volume of electricity purchased from the solar arrays will depend on weather and insolation. The batteries can bid 1 MW of capacity into the NYISO frequency regulation market, and may be able to engage in some degree of TOU bill management and peak demand charge reduction. However, to engage in effective TOU bill management and peak demand charge reduction, the microgrid would have to operate in island mode in order to aggregate sufficient electricity supply and demand behind one meter. The legal regulations and complications associated with extended islanded operation are discussed in the Appendix.

The battery storage units are capable of participation in DR programs, but they must maintain a certain level of charge to prepare for unexpected grid outages and the NYISO frequency regulation market provides more lucrative payments for capacity. The microgrid is capable of intentionally entering island mode without disconnecting downstream loads, but it is unclear whether doing so will qualify for participation in DR programs, as island mode removes both generation and load off the larger grid.

The batteries also provide several non-cash value streams to the utility and NYISO. Together these non-cash value streams can be worth as much as $610/kW-year.[23] The storage units can be used as an alternative to building new power plants to meet peak demand (resource adequacy), can be discharged downstream of congested corridors to minimize congestion costs during peak demand events (transmission congestion relief), and can delay, reduce, or remove the need for investments in the utility's transmission system (transmission deferral). The Project Team did not assume revenue from these non-cash value streams, but by appropriately compensating SPV investors, NYSEG and NYISO could make the Liberty microgrid a more attractive investment.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to Liberty, private investors, NYSEG, direct participants, and the larger State of New York. The new solar arrays will produce zero-emission energy in both normal and islanded operation, and the new battery storage units will firm the output curve and provide an energy bank for emergency outages. SPV members will receive stable revenues, though consistently negative operating cash flows, from operation of the proposed energy resources throughout the life of the project. Depending on the regulatory environment and the willingness of NYSEG and New York State to compensate the microgrid for non-cash value streams, SPV members may be able to realize additional cash flows that make the project a more attractive investment. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

Table 11 below provides an overview of the Liberty microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

[23] NYSERDA estimates through the Rocky Mountain Institute, "The Economics of Battery Storage."

Table 11. Liberty Microgrid SWOT Analysis

The strengths, weaknesses, opportunities, and threats (SWOT) associated with the Liberty microgrid project.

Strengths	Weaknesses
• Full NYSEG participation in ownership of the infrastructure hardware and potentially of the control system may demonstrate to other IOUs the value of community microgrids in their service territories and prove out a win-win for the utility and ratepayers • Allows for the use of existing T&D infrastructure, thereby reducing the potential cost burden of constructing new lines and feeders (microgrid project will only require isolation switches to disconnect the microgrid from the feeder and downstream loads) • Local generation will reduce congestion and the need for additional supply side resources during peak demand events, providing non-cash value to NYSEG throughout the year • Draws on NYSEG's expertise to facilitate daily operation of the microgrid (load aggregation, load following, voltage regulation, and other requirements) • Engages key critical facilities as well as local residents and businesses	• Selling electricity and ancillary services will not recover all initial investment costs. The commercial feasibility of the project therefore depends on funding from NYSERDA, NYSEG, or New York State • Separating significant capital costs from the revenues necessitates further agreement between revenue drivers (DERs) and control infrastructure owners (NYSEG). DER owners may balk at diverting revenue to non-revenue generating components
Opportunities	**Threats**
• Encourages teamwork between local government, private investors, and local IOU. Because most communities are served by IOUs, this model could serve as a template for future projects • Demonstrates the feasibility of reducing load on the larger grid with distributed energy resources • Provides a proof point for utility operated microgrids in partnership with DER investor group • Provides data for NYSEG and NYSERDA on the benefits of using paired solar energy and battery storage systems. If successful, the paired solar/storage model could be applied to multiple towns throughout the state that do not have access to natural gas • The cost of battery storage is constantly decreasing, and by "stacking" different uses, SPV investors may soon be able to achieve a competitive levelized cost of storage[24]	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals. • While currently lucrative, the frequency regulation market is thin. As more DERs across the state bid capacity into the market, the average price that NYISO pays for this ancillary service will likely decline, which would cause a drop in microgrid revenues

[24] Lazard's Levelized Cost of Storage, Version 1.0.

Although there are several valuable strengths and opportunities associated with the hybrid ownership model, there are also weaknesses and threats that must be addressed and, if possible, mitigated.

- **Financial** – First, SPV members will seek a long-term PPA, or some other form of long-term purchase agreement, with NYSEG to guarantee steady future revenue streams from electricity sales. As long as the agreement reliably guarantees fair compensation for generator output over the project lifespan, SPV members must be content with flexible compensation rates and a low amount of risk. Second, revenues from sale of electricity and ancillary services are projected to be insufficient to cover operating expenses. This weakness is partially offset by NY Prize Phase III funding, which is a requirement for project viability. Without further subsidization the project is unlikely to attract investor interest. Finally, revenue from ancillary service sales will likely decline in the future as more participants enter the frequency regulation market and prices decline. SPV members can partially mitigate this threat by switching use of the battery storage units to other services such as energy arbitrage or participation in demand response programs.
- **Organizational Competition** – This business model requires collaboration among groups of stakeholders that may have different motivations for participation in the microgrid project. NYSEG may construct and own non-revenue generating control and switchgear with an expectation of financial support from DER revenues. DER owners may be disinclined to support the non-revenue assets. Open communication and early agreement between NYSEG and private DER investors regarding operational parameters, volumes of electricity to be purchased, and the price per unit of electricity will be paramount for the smooth operation of the microgrid.
- **Regulatory** – Utilities in New York State cannot own generation assets unless they demonstrate why full vertical integration provides value to their customers. The State of New York wishes to avoid situations in which a single entity monopolizes energy generation and distribution resources. Utilities may not purchase DERs, and microgrid investors that purchase distribution infrastructure may be considered utilities. To avoid this regulatory threat, the SPV will purchase only new generation assets, while NYSEG will retain ownership of existing power lines and new distribution infrastructure. The proposed business model will therefore function within the existing regulatory landscape and may provide evidence that privately owned generation assets can successfully sell electricity over a utility-owned power distribution platform.

3.2.2 Replicability and Scalability

The Liberty microgrid is a largely replicable and scalable model, and it is being designed with industry standard equipment and software that can be applied to diverse existing infrastructure. The proposed generation assets qualify for a significant total incentive payment—the NY Sun program may offset 15-30% of the solar arrays' capital cost, and the Federal investment tax credit (ITC) may offset an additional 30% of capital costs from the solar arrays. However, because operating revenues are relatively low and operating costs are high, the project's commercial viability depends on NYSERDA NY Prize Phase III funding and additional subsidies, which will not be available to most community microgrid projects. This hinders the project's replicability unless the NYPSC issues policy changes incentivizing microgrid development.

Technical Replicability. The proposed microgrid technology does not present a barrier to project replicability. The primary components of the microgrid, including the proposed generation assets, switches, and microgrid control system, are widely available and could be repeated in any given location. All interconnections with the NYSEG grid are industry standard. However, the proposed microgrid is located at the end of the Liberty 145 feeder, which allows intentional transitions to island mode without disconnecting downstream loads. Other community microgrids that must disconnect downstream loads in order to enter island mode cannot use battery storage units for TOU bill management across the entire microgrid or disconnect from the grid to participate in DR programs.[25]

Organizational Replicability. Because most municipalities in NYS follow a similar electricity model in which the local IOU distributes power purchased from third-party owned generation assets, the project's power distribution structure is easily replicable. Private DER ownership that contracts the local utility to operate the DERs, coupled with utility infrastructure ownership, is both replicable and desirable as it brings private capital into the energy arena and provides a platform for utilities to realize revenue from the projects. A model in which an IOU has some degree of operational control over the generation assets without any financial stake in them is not one that has been widely implemented. It is the opinion of the Project Team, however, that the proposed model provides a path ahead for grid-integrated microgrids in a fashion that engages utilities, which may otherwise be skeptical of their value proposition. The model may also promote innovations in rate calculations and help change the services that IOUs are expected to provide. Its replicability expands the potential market for resulting innovations to include a larger part of New York State. As such, this project presents a valuable opportunity for NYSERDA to examine the changing role of the investor-owned utility in energy generation and distribution.

Scalability. The Liberty microgrid is scalable on the Liberty 145 feeder. However, expansion to another feeder would require addition of new isolation switches, expanded generation, additional power flow studies, and would forfeit the valuable capability of intentional islanding. It also assumes congruent line voltage, without which the linkage of different feeders would become more electrically complex.

Although the project is technically scalable, adding loads would require additional solar PV arrays and battery storage units. The high capital costs of adding more DERs that do not produce significant revenues may discourage expansion of the Liberty microgrid.

[25] These communities may still use battery storage units for TOU bill management at individual facilities, but individual facility load rarely is high enough to produce significant revenues.

3.2.3 Benefits, Costs and Value

The microgrid will provide widely distributed benefits, both direct and indirect, to a multitude of stakeholders. The SPV will receive stable revenues for the lifetime of the project, the Town and citizens will benefit from a more resilient electricity system, and the community will reap the positive effects of living in and around the microgrid during times of emergency. These costs and benefits are described in Tables 12 through 17. Moreover, the local community will not bear any of the project's costs. However, without funding from NY Prize Phase III and additional subsidies, the cash flows generated by proposed DERs will not cover operating costs. This proposal involves a wide group of stakeholders—from local, non-customer residents to the State of New York—and provides value to all involved parties.

Tables 12 through 17 below provide an overview of the benefits and costs to members of the SPV, direct microgrid customers, citizens of Liberty and surrounding municipalities, and the State of New York.

Table 12. Benefits, Costs, and Value Proposition to SPV

SPV shareholders will receive stable revenues from the microgrid project for the lifetime of the project.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
SPV	- Investors will receive annual revenues from sale of electricity and ancillary services - NY Sun incentive recovers 15-30% of solar arrays' cost in the project's first year - Federal ITC recovers 30% of the cost of solar arrays - NY Prize Phase III funding may recover 50% of capital costs - Depending on the regulatory environment surrounding continuous operation in island mode, the microgrid may achieve some savings by deploying the batteries for effective TOU bill management and peak demand charge reduction. These savings would be remitted to the SPV as the owner of the battery storage units	- Initial capital outlay will be high because the SPV must purchase and install generation assets (including three expensive battery storage units) - Forecasted installed capital costs for the solar arrays and battery storage units are $1.575 MM and $2.5 MM, respectively - Ongoing maintenance of DERs - Financing costs associated with initial capital outlay will persist for many years	- Long-term purchase contracts make revenues from electricity sales low risk, however the high capital and operating costs cannot be recovered without significant subsidy

Table 13. Benefits, Costs, and Value Proposition to NYSEG

NYSEG will receive new revenues from the operation of the microgrid while bearing only a fraction of initial and ongoing costs.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
NYSEG	- The utility will continue to sell electricity to direct customers - NYSEG will maintain full control of distribution lines and potentially also the new control infrastructure - Local generation reduces the amount of power that must be imported from the larger grid - By discharging batteries during peak demand events, NYSEG can flatten the output curve and may realize overall system savings - Improved reliability provided to customers within the microgrid footprint	- NYSEG will purchase electricity from the solar arrays at a price consistent with its existing electricity supply costs - NYSEG may bear the cost of installing and maintaining microgrid infrastructure	- The utility can serve as a market connector, realizing revenue from T&D and fees from the DERs - Improved grid resilience by integrating local generation assets with local distribution networks - NYSEG will have a new supply of electricity valued at their average supply charge but may marginally reduce their T&D costs in the immediate area

Table 14. Benefits, Costs, and Value Proposition to the Town of Liberty

Liberty will become a leader in achieving NY REV goals by providing a local market for DER-generated electricity and catalyzing investment in DER assets.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Town of Liberty	- Several municipal facilities will receive backup power from proposed DERs—this will reduce the need for future investments in backup generation capabilities - The microgrid will provide a resilient and redundant energy supply to critical services - Reduced greenhouse gas emissions and progress towards state energy goals	- When the microgrid enters island mode due to a larger grid outage, customers may pay a slightly higher price for electricity than they would for electricity from the larger grid, pending contract negotiations in Phase II. This cost is offset by enhanced reliability and power quality	- Critical and important services will maintain power during outages, allowing the Liberty microgrid to serve as a relief point for the local community - The microgrid project will serve as a catalyst for engaging customers in energy service opportunities and will inspire residential investment in DERs, such as solar PV and battery storage, as citizens see benefits associated with avoiding peak demand hours and producing enough electricity to be independent from the larger grid - Generating electricity with the new solar PV array and firming the output curve with storage will provide reliable, zero-emission electricity and reduce greenhouse gas emissions

Table 15. Benefits, Costs, and Value Proposition to Connected Facilities

Connected facilities will benefit from a more resilient energy supply and may choose to invest in small DERs of their own.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	- Resilient and redundant energy supply - Access to a local market for DERs makes investments in small DERs more attractive to connected facilities - Possible use of battery storage units would allow connected facilities to shift solar production to peak hours and realize more competitive returns	- When the microgrid enters island mode due to a larger grid outage, customers may pay a slightly higher price for electricity than they would for electricity from the larger grid, pending contract negotiations in Phase II. This cost is offset by enhanced reliability and power quality	- Maintain operations during emergency outages and provide valuable critical services to the Liberty community - Local market for excess energy makes investments in small DERs (such as solar panels) profitable for connected facilities

Table 16. Benefits, Costs, and Value Proposition to the Larger Community

Community will have access to critical services during grid outages.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a wide range of critical and important services during grid outages - Reduced greenhouse gas emissions and progress towards state energy goals	- Because the larger community will not be connected to the microgrid, this stakeholder group will not bear any significant costs.	- Potential for reconnect in outage situations if generation assets are out-producing the demanded critical loads and the footprint of the microgrid is expanded - Future expansion of the microgrid could bring more facilities into the design—however, Liberty will likely need to install advanced metering infrastructure (AMI) meters for this to be feasible

Table 17. Benefits, Costs, and Value Proposition to New York State

The microgrid provides a tangible example of a Town working towards a significant NY REV goal: to expand the privately-owned DER industry by providing a local, utility-owned power distribution platform.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	- Indirect benefits (such as outages averted, transmission upgrade deferral, congestion cost reduction, etc.) will demonstrate the benefits of microgrids paired with DERs to citizens across the state and reduce load on the larger grid - Each microgrid accelerates NY state's transition from old macrogrid technology to newer, smarter, smaller technologies - Reduced greenhouse gas emissions and progress towards state energy goals - Meet NY Reforming the Energy Vision goals by encouraging DER construction and improving energy resiliency	- The State may need to compensate the project for the indirect benefits it provides in order to attract sufficient investor interest	- Successful construction and operation of a community microgrid will demonstrate the societal value of microgrid projects - Indirect benefits associated with microgrids will encourage and inspire citizens to strive for DER in their own communities - Success of SPV model aligns with REV goals—this project provides an example of investor-owned generation assets selling electricity over a utility-owned power distribution platform

3.2.4 Demonstration of State Policy

The proposed microgrid represents a major step towards achieving New York State energy goals; it will provide a local platform for excess energy generation throughout the year, help the community adapt to climate change, and significantly expand renewable energy generation in Liberty. The proposed microgrid supports the New York State Energy Plan by providing a power distribution platform for locally-owned DERs.

By coordinating the microgrid as a local distributed system platform (DSP), the Liberty microgrid will act as a distributed resource and will provide local grid stabilization through injections and withdrawals of power. As more distributed resources are added throughout the Town, the microgrid can be tuned to provide continual support for these assets (e.g., by providing ancillary services) and will diversify and enhance its portfolio of revenue streams. Eventually, as more microgrids arise in New York State, the proposed microgrid can integrate seamlessly into a larger "grid of grids" to promote energy markets, trading, and enhanced consumer choice for preferred power source.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes NYSEG, the Town of Liberty government, Booz Allen Hamilton, Siemens AG, and Power Analytics. It may expand to include financiers as the project develops. Details on the Project Team can be found in this section.

3.3.1 Stakeholder Engagement

The Project Team has been engaged in constant communication with local stakeholders from the outset. Booz Allen and its Town partners have also communicated with each of the proposed facilities to gauge electricity demand and discuss other aspects of project development.

3.3.2 Project Team

The Liberty microgrid project is a collaboration between the public sector, led by the Town of Liberty, and the private sector, led by Booz Allen Hamilton with significant support from Power Analytics, Siemens, and NYSEG. Each of the private sector partners is well qualified in the energy and project management space, and Liberty has strong interest in improving its energy reliability and expanding its clean energy generation capacity. Tables 18 and 19 provide details on the Project Team.

Table 18. Project Team

Background on Booz Allen Hamilton, Siemens AG, Power Analytics, and NYSEG.

Booz Allen Hamilton	**Headquarters: McLean, VA**	**Annual Revenue: $5.5 B**	**Employees: 22,700**
History and Product Portfolio: Booz Allen was founded in 1914 and in the ten decades since its founding, Booz Allen has assisted a broad spectrum of government, industry, and not-for-profit clients including the American Red Cross, all branches of the Department of Defense, the Chrysler Corporation, NASA, and the Internal Revenue Service. Booz Allen's energy business includes helping clients analyze and understand their energy use and develop energy strategies, recommending technology solutions to achieve their energy goals, and executing both self- and 3rd party funded projects including energy efficiency, renewable energy, and smart grids.			
Siemens AG	**Headquarters: Munich, Germany; U.S. Headquarters: Washington, DC**	**Annual Revenue: €71.9 B**	**Employees: 343,000**
History and Product Portfolio: Siemens AG was founded in 1847 and today is one of the world's largest technology companies. Siemens AG specializes in electronics and electrical engineering, operating in the industry, energy, healthcare, infrastructure, and cities sectors. Siemens AG develops and manufactures products, designs and installs complex systems and projects, and tailors a wide range of solutions for individual requirements. The Siemens Microgrid Team develops comprehensive solutions leveraging the strength of Siemens' portfolio – from generation sources such as gas, wind, and solar, to transmission & distribution products, to control software solutions and services.			
Power Analytics	**Headquarters: San Diego, CA**	**Annual Revenue: $10-15 MM**	**Employees: 50**
History and Product Portfolio: Founded 25 years ago, Power Analytics is a privately-held small business that develops and supports electrical power system design, simulation, and analytics software. The Company's worldwide operations include sales, distribution, and support offices located throughout North America, South America, Europe, Asia, and Africa and Australia.			
NYSEG	**Headquarters: Orange, CT**	**Annual Revenue: $1.63 B**	**Employees: 7,000**
History and Product Portfolio: A subsidiary of AVANGRID, NYSEG is an electrical and gas company operating in New York State. NYSEG provides electric service to approximately 890,000 customers and gas service to approximately 262,000 customers across more than 40% of upstate New York. AVANGRID receives yearly operating revenues of approximately $1.63 billion and is headquartered in Orange, CT.			

Table 4. Project Team Roles and Responsibilities

Table outlines roles, responsibilities, and expectations for each member of the Project Team during development, construction, and operation of the microgrid.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
NYSEG	NYSEG will work with the Project Team to develop the concept and provide input. They will further provide the financial support for the purchase of microgrid control systems and infrastructure.	NYSEG may provide a share of the initial capital outlay that corresponds to the microgrid control infrastructure.	NYSEG may provide the necessary domain expertise to operate and maintain the microgrid infrastructure. This includes responsibility for switching to island mode and regulating voltage and frequency across the microgrid's loads in both grid-connected and island mode. Through the microgrid control system, the utility will have some degree of control over charge and discharge of batteries.
Town of Liberty, Sullivan County Alliance for Sustainable Development (SASD)	SASD will serve as the main conduit to representatives of the critical and important facilities and other interests in the Town.	As the liaison, SASD will coordinate with all local and state parties as needed.	As the liaison, SASD will coordinate with all local, regional, and state parties as required.
Booz Allen	BAH is responsible for the delivery of the Feasibility Study and its component parts. This includes serving as the central clearinghouse of data, design, and proposal development as well as the key POC for NYSERDA on this task.	BAH will serve in an advisory and organizational role, working in a similar prime contractor capacity to provide overall design, costing, and construction management services.	BAH would serve in an outside, advisory capacity upon completion of the microgrid and during its operation.
Siemens	Siemens is the engineering and technology partner of this project. They will develop the technical design and system configuration in concert with BAH engineers and the Power Analytics team.	Siemens may have primary responsibility for the shovel-in-the-ground construction and installation of hardware and generation assets.	Ensuring proper functioning and maintenance of the microgrid technology components throughout.
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics may lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Provide IT systems support; may play an active role in system management through the EnergyNet software platform.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Suppliers	There are no suppliers required during the development phase; however, project partners and suppliers Siemens and Power Analytics are closely involved in feasibility and design portions of the project. BAH is in touch with several additional suppliers of hardware and software including Duke Energy, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	Siemens or another engineering and technology firm will be the hardware supplier, including switches and other physical controls. Power Analytics or another software company will be the EMS and SCADA provider, responsible for software and server components.	The installer of the hardware and software will continue to provide maintenance and advisory services as required to ensure proper and efficient functioning of their components. The software provider will work in cooperation with NYSEG to assess the best approach to daily operations of the software system.
Financiers/Investors	The SPV will be created during the project development phase. Investors for DERs may include any of the entities mentioned in the row above.	Debt and equity investors will supply the cash required to complete the construction and installation of generation assets and microgrid controls.	Generation asset owners will realize revenues from the sale of electricity and ancillary services. NYSEG will realize revenues from payments from DER owners.
Legal/Regulatory Advisors	Regulatory advice is housed within Booz Allen. Further counsel will be retained as necessary to create the SPV and arrange financing.	Legal and regulatory will be a combination of Booz Allen, the Town, NYSEG, and any outside counsel required.	Legal and regulatory will be the responsibility of the Town, the utility, and any investors in the SPV

3.3.3 Financial Strength

The principal shareholders in the microgrid project are NYSEG and private investors, through the SPV.

Moody's Investor Service rates NYSEG at a Baa1 credit rating. According to the Moody's rating scale, "Obligations rated Baa are judged to be medium-grade and subject to moderate credit risk and as such may possess certain speculative characteristics." NYSEG is a subsidiary of AVANGRID, a U.S. based diversified energy and utility company. AVANGRID is an affiliate of the Spanish energy company Iberdrola and employs nearly 7,000 people across the United States. NYSEG provides electric service to approximately 879,000 customers and gas service to approximately 262,000 customers across more than 40% of upstate New York. AVANGRID receives yearly operating revenues of approximately $1.63 billion.

Given the high capital costs for large scale energy storage and the relatively low operating revenues from proposed DERs, outside investors will not have interest in the Liberty microgrid project unless NYSEG, NYISO, or the state government compensates the SPV for the non-cash value of battery storage and subsidizes microgrid infrastructure.

3.4 Commercial Viability – Creating and Delivering Value (Sub Task 3.4)

The specific technologies included in the microgrid design will enable rapid and efficient transitions between grid-connected and island mode based on signals from a SCADA control center. The proven efficacy of proposed microgrid components enhances the replicability and scalability of the design. This section will discuss the technical components of the microgrid and why they were chosen.

3.4.1 Microgrid Technologies

The specific technologies included in the microgrid design were chosen to meet the goals of providing reliable and efficient power in both grid-connected and island mode, achieving automatic load following, and developing black-start capability.

Because there is no natural gas infrastructure in Liberty, the design relies on battery storage systems for energy resiliency. Solar PV arrays will provide significant zero-emission energy generation throughout the year, moving Liberty and New York State closer to the renewable generation goals set forth in the state energy plan and the Renewable Portfolio Standard. If the battery units exhaust their charges in island mode, the microgrid is equipped with a small diesel generator that will come on-line and provide supplemental power as necessary. The battery storage units will be capable of automatic load following (responding to load fluctuations within cycles, allowing the microgrid to maintain system voltage and frequency) and black starts. The batteries will also greatly reduce the need for diesel generation in emergency outage situations.

The Liberty microgrid includes numerous components that have been previously used and validated. Solar PV and standby diesel generators are widely used technologies, with more than 6 gigawatts of solar PV installed in 2015 in the United States. The switch components are all industry standard and are widely used in utilities worldwide, and the IEDs, which are robust and safe via embedded electrical protections, are similarly standard across the industry. Siemens microgrid technologies are recognized worldwide for their flexibility, reliability, and expandability—successful examples of Siemens microgrid technology at work include the Parker Ranch and Savona University microgrids.[26] Team partner Power Analytics has similarly successful implementations of its Paladin software in microgrid environments, including the 42 MW, 45,000 person UC San Diego microgrid project.[27]

The proposed battery storage units use an emerging zinc-air cell technology. Because it is so new, this technology has not accumulated much operational data. However, one manufacturer, Eos Energy Storage, predicts the battery will last 5,000 cycles at greater than 75% efficiency per discharge, and plans to sell the batteries at $160/kWh.[28] The batteries' uses include, but are not limited to, peak shaving, long term energy storage, and frequency regulation. The batteries will require inverters to synchronize their DC output with the alternating current (AC) electricity

[26] Siemens case studies; available from http://w3.usa.siemens.com/smartgrid/us/en/microgrid/pages/microgrids.aspx.
[27] http://www.poweranalytics.com/company/pdf/M-12-GE-PPT-X-001-03%202012%20UCSD%20Virtual%20summit.pdf.
[28] Eos Aurora: http://www.eosenergystorage.com/products/.

flowing through the larger grid and intelligent controls to synchronize with the microgrid control system.

3.4.2 Operation

SPV investors will direct a portion of revenues to NYSEG to support the operation and maintenance of the microgrid. As the project's subject matter expert and owner of the distribution infrastructure, NYSEG will provide advice regarding the logistics of day-to-day operation. Regular maintenance and checks of equipment will be conducted based on manufacturer or installer recommendations and will ensure the proper function of all grid elements.

NYSEG will have final authority on decisions regarding the microgrid that are not automatic elevations to the state or NYPSC. Decisions regarding the proper level of generation from local assets, load following, N+1 assurance, and other similar issues will be addressed automatically in real-time by the logic controllers and the MCS. The decision algorithms will be programmed upon installation with input from the utility and with the ability to alter or revise them if operations dictate that to be the appropriate action. Interactions with the NYSEG power grid will be automatically governed by the microgrid controllers.

This analysis assumes NYSEG will purchase electricity from the solar PV arrays and distribute it across its grid. The facilities will continue to be billed for electricity via the regular NYSEG billing mechanism and cycle. Additional fees may be imposed upon microgrid participants as a percentage of their electricity cost. However, given the extremely limited amount of time forecasted in island operation and the commensurately limited time the customers will need to rely on the microgrid, the fee will be negligible or nonexistent.

3.4.3 Barriers to Completion

The barriers to constructing and operating the microgrid are primarily financial. The lack of natural gas infrastructure forces the Liberty microgrid to rely on large scale energy storage to achieve necessary resiliency. Although there have been significant advancements in battery technology in recent years, batteries still incur high capital costs and produce relatively little revenue. NYSERDA and the New York Battery and Energy Storage Technology Consortium (NY-BEST) have not developed incentive programs outside of Consolidated Edison's service territory in New York City, so project owners will have to rely on cash flows from ancillary services, energy arbitrage, or DR programs in order to recoup investment costs. Assuming the SPV will sell electricity to NYSEG at their current supply charge and will bid 1 MW of capacity into the NYISO frequency regulation market, the microgrid will produce negative operating cash flows from year to year. This means revenues will not cover operating costs and there will be no possibility of recovering capital expenditures.

3.4.4 Permitting

The Liberty microgrid may require certain permits and permissions depending on the ultimate design choices. The proposed solar arrays and battery storage units qualify as "Changes and Additions," and as such require permits under local codes 147-32 and 147-38. The SPV will need to apply to the local Code Enforcement Officer for a permit, who may grant, refuse, or refer the application to the Planning Board or Zoning Board of Appeals. Liberty is not in any Environmental Protection Agency (EPA) Criteria Pollutant Non-Attainment zones.

3.5 Financial Viability (Sub Task 3.5)

The distributed energy resource assets included in the microgrid design will produce revenue streams from electricity sales to NYSEG and sale of ancillary services to NYISO. These assets will require significant initial capital outlay as well as annual operation and maintenance costs. The microgrid project qualifies for the NY Sun incentive and the Federal ITC, which may partially offset the initial investment costs. Private investors will use a mix of debt and equity to finance their shares. This section will discuss the revenues, costs, and financing options associated with the microgrid project in more detail.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 20. The revenues will sum to approximately $85,000 per year, while operation and maintenance for generation assets and microgrid infrastructure will cost around $130,000 per year. However, SPV members may be able to unlock other revenue streams by engaging in TOU bill management (see Appendix) or obtaining appropriate subsidies for non-cash values from NYSERDA or NYSEG (see Table 21 for potential value streams). In the conservative base case, yearly cash flows will be negative and will not recover initial investment costs. The commercial viability of the Liberty microgrid project is therefore dependent on Phase III NY Prize funding and operating subsidies.

Table 20. Savings and Revenues

Expected revenues and savings directly associated with operation of the microgrid and its DERs.

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from new solar PV arrays[29]	Revenue	~$45,000/yr	Variable
Revenues from frequency regulation services	Revenue	~$40,000/yr	Variable
Total Yearly Revenue and Savings		~$85,000/yr	Variable

The Project Team assumed the battery storage units can bid 1 MW into the New York frequency regulation market throughout the year. In 2015, the average payment per MW per service hour was $9.23. Assuming a conservative capacity factor, the battery units will be available for frequency regulation services for approximately 4,380 hours per year.[30] This translates to yearly revenues of approximately $40,000 per year, or a value of around $40.41 per kW per year. The Project Team has assumed the energy used for these frequency regulation services has a net-zero dollar value. This is a conservative assumption, as the battery will likely be required to charge

[29] The Booz Allen Team calculated NYSEG's supply charge for electricity to be approximately $0.0605/kWh in WEST zone. This is the assumed price for grid-connected sales from the solar PV arrays.
[30] Method adapted from Sandia National Laboratories, "Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide."

(down regulate) when NYISO wholesale prices are low and discharge (up regulate) when NYISO wholesale prices are high.

Table 21. Possible Values from Batteries

Potential cash and non-cash value streams associated with battery storage units.

Description of Savings and Revenues	Cash or non-cash	Relative Magnitude	Fixed or variable
TOU bill management[31]	Cash (savings)	~$40,000/yr	Variable
Peak demand charge reduction[32]	Cash (savings)	~$20,000/yr	Variable
Resource adequacy (use storage as an alternative to building new power plants to meet peak demand)[33]	Non-cash	~$23,000/yr	Fixed
Transmission congestion relief (use storage downstream of congested corridors to minimize congestion costs during peak demand events)[34]	Cash (savings)	~$2,000/yr	Variable
Utility transmission deferral (delay, reduce, or remove the need for utility investments in the transmission system)[35]	Non-cash	~$115,000/yr	Fixed
Total Potential Values		~$200,000/yr	Variable

[31] Based on 230 kW available for TOU bill management (average microgrid electricity demand) and a value of $180/kW-year (Sandia National Labs through the Rocky Mountain Institute, "The Economics of Battery Energy Storage").
[32] Based on 230 kW available for TOU bill management (average microgrid electricity demand) and a value of $90/kW-year (Sandia National Labs through the Rocky Mountain Institute, "The Economics of Battery Energy Storage").
[33] Based on 230 kW available for discharging during peak demand events (average microgrid electricity demand) and a value of $100/kW-year (NYSERDA through the Rocky Mountain Institute, "The Economics of Battery Energy Storage").
[34] Based on 230 kW available for discharging (average microgrid electricity demand) and a value of $10/kW-year (NYSERDA through the Rocky Mountain Institute, "The Economics of Battery Energy Storage").
[35] Based on 230 kW available for discharging (average microgrid electricity demand) and a value of $500/kW-year (NYSERDA through the Rocky Mountain Institute, "The Economics of Battery Energy Storage").

Table 22. Capital and Operating Costs

Expected costs from construction and operation of the microgrid.

Description of Costs[36]	CapEx or OpEx	Relative Magnitude	Fixed or Variable
450 kW Solar PV array (carport)	Capital	$1,215,000	Fixed
150 kW Solar PV array (roof-mount)	Capital	$360,000	Fixed
12 MWh Battery storage[37]	Capital	$2,500,000	Fixed
200 kW diesel	Capital	$200,000	Fixed
Distributed Equipment	Capital	$110,000	Fixed
Microgrid Control System	Capital	$450,000	Fixed
IT costs (wireless and cables)	Capital	$50,000	Fixed
Total CapEx		$4.89 MM	Fixed
Design considerations and simulation analysis	Planning and Design	$575,000	Fixed
Project valuation and investment planning	Planning and Design	$75,000	Fixed
Assessment of regulatory, legal, and financial viability	Planning and Design	$50,000	Fixed
Development of contractual relationships	Planning and Design	$50,000	Fixed
Total Planning and Design		$750,000	Fixed
Battery Maintenance	Operating	$50,000/yr	Variable
Solar PV Maintenance	Operating	$12,000/yr	Variable
Diesel fuel and O&M[38]	Operating	$1,300/yr	Variable
Microgrid Control O&M	Operating	$70,000	Fixed
Total OpEx		$130,000/yr	Variable

The proposed microgrid should qualify for two existing incentive programs: the NY Sun program and the Federal ITC for solar PV arrays, see Table 23. NY Sun may cover 15-30% of each solar array's capital cost, and the Federal ITC may recover an additional 30%. The Federal ITC also applies to battery storage units that charge at least 75% of their energy from renewable sources, but the Project Team does not expect the proposed storage units will consistently meet

[36] Non-battery capital and O&M costs provided by Siemens based on industry standard figures.
[37] Capital estimate includes $160/kWh plus 30% for installation costs for a total of approximately $210/kWh. Zinc air battery storage is a new technology that is significantly cheaper than other storage technologies because half of the electrolyte (Oxygen) is free. Companies such as Fluidic Energy and Eos Energy Storage, both members of the New York Battery and Energy Storage Technology Consortium (NY BEST), have pioneered this technology in recent years with successful results.
[38] Based on a projected 40 hours of use per year.

this criterion. Other possible sources of incentive payments include NYSERDA Phase III NY Prize funding (up to $5 million with a 50% cost share burden on the project).

Table 23. Available Incentive Programs

State and utility incentive programs that were included in the commercial/financial feasibility analysis and whether the incentive is required or preferred for the microgrid project to be feasible.

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase III	$2,450,000	Required
NYSERDA NY Prize Phase II	$750,000	Required
NY Sun	~$290,000	Required
Federal Solar ITC	~$470,000	Required

3.5.2 Financing Structure

The development phase is characterized by the negotiation and execution of the construction financing and debt structure and agreements with any equity partners. Awards from Phase II of the NY Prize Community Microgrid Competition would supply most of the funding for project design and development, with the SPV providing capital for any costs that exceed available NYSERDA funding. The Project Team anticipates NYSERDA to supply 75% of the required funds for Phase II with the balance coming from a cost-share. This is based on the Phase II cost structure as described in NYSERDA RFP-3044. Liberty and their Project Team would provide cash support or needed in-kind services consisting primarily of system expertise and support. Development will conclude with formal contract relationships between the utility and the customers of the microgrid, available and relevant rate and tariff information from the NYPSC, and firm financing for the construction of the project (described below).

The project requires Phase III funding from NYSERDA to complete the construction phase. Phase III NY Prize funding, would cover half of the capital cost of the project (estimated to be approximately $2.45 MM in total), and private and utility funding would represent the balance of the financing.

The Project Team assumes the Liberty Elementary School will grant the physical space to site the DERs at no cost because they will be one of the primary beneficiaries of the proposed microgrid. Paired solar and storage systems also present valuable learning opportunities for students throughout the Town. The SPV will maintain ownership over all generation assets and NYSEG over the control infrastructure.

3.6 Legal Viability (Sub Task 3.6)

Like any infrastructure project that involves development of public and private land, the Liberty microgrid project will require legal and regulatory agreements for ownership, access, zoning, permitting, and regulation/oversight. This section considers the various legal aspects of the microgrid project and discusses the likelihood of each becoming an obstacle to the project's success.

3.6.1 Regulatory Considerations

State and Utility Regulation

The new DERs will be regulated under relevant State code, however the process for constructing small distributed energy resources in New York is well established. The microgrid will comply with all rules governing the interconnection of generation assets to the grid, and given NYSEG's close participation in the project the Project Team does not envision any onerous requirements.

Local Regulation

All entities that require the use of public ways (i.e., for transmission or distribution facilities) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. Towns in New York have specific statutory authority to grant franchises. As provided by N.Y. Vil. Law § 4-412, every Town Board of Trustees is empowered to grant franchises or rights to use the streets, waters, waterfront, public ways, and public places of the city.[39] "Use" encompasses occupying public rights-of-way and operation of the provider's built infrastructure to provide the public service.[40] As the distribution infrastructure already exists in Liberty, new permissions for the running of lines should not be a concern. As outlined in Town zoning documents, a zoning permit is required for the modification in use of any property and this may apply to the accessory addition of distributed energy resources. Given the relatively small scale of the proposed generating assets and the municipal support for the project, the Project Team does not foresee this condition as prohibitive.

Air Quality

Diesel generators may be subject to a variety of federal permits and emission standards depending on the type of engine, the electrical output of the system, how much electricity is delivered to the grid versus used onsite, and the date of construction. The specific details associated with the proposed standby diesel generator in Liberty will determine the applicability of the regulations below. CAA regulations applicable to Reciprocating Internal Combustion Engine systems, specifically for compression ignition emergency/limited use diesel generators, will apply. These regulations include:

[39] N.Y. Vil. Law § 4-412.

[40] See, e.g., "Contract of April 7, 1887 between Hess et al. Commissioners & Consolidated Telegraph & Electrical Subway Co." (Con Tel and Electrical Subway Company Agreements 1886-1891.pdf).

- National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines (RICE): 40 CFR part 63 subpart ZZZZ
- New Source Performance Standards (NSPS) for Stationary Compression Ignition (CI) Internal Combustion Engines (ICE): 40 CFR part 60 subpart IIII

Per EPA guidance, these regulations apply to all engine sizes, regardless of the end use of the power generated. Compliance requirements for emergency/limited use diesel generators include initial notification of construction, regular reporting of operation levels, and use of ultra-low sulfur diesel (ULSD) fuel. However, further review and analysis must be conducted when details of the type and size of the generation system are confirmed.

New York state has enacted amendments to Environmental Conservation Law Articles 19 (Air Pollution Control) and 70 (Uniform Procedures) as well as New York State Department of Environmental Conservation (NYS DEC) amended regulations 6NYCRR Parts, per the 1990 Amendments to the Clean Air Act. With this demonstration of authority, NYS DEC received delegation of the Title V operating permit program from the EPA. Title V Permits are required for all facilities with air emissions greater than major stationary source thresholds. New York's air pollution control permitting program combines the federal air operating permitting program with long-standing features of the state program. The primary rules for applications are found in 6NYCRR:

- 200 (General Provisions),
- 201 (Permits and Certificates),
- 621 (Uniform Procedures) and
- 231 (New Source Review in Non-attainment Areas and Ozone Transport Regions).

Final application of these rules will depend on the size and technology of the selected diesel unit.

3.7 Project Commercial and Financial Viability Conclusions

The proposed microgrid's commercial feasibility depends on NY Prize Phase III funding and additional subsidies. The Project Team forecasts yearly revenues of approximately $85,000 and yearly operation and maintenance costs of approximately $130,000, plus capital expenditures of $4.89 million. The project will produce negative annual operating cash flows, and it will require subsidies to fully recover operating costs and initial investment costs.

These estimates and value propositions are predicated on several assumptions.

- Private investors will own the DERs, and NYSEG may own the distribution infrastructure. Although NYSEG has neither confirmed nor denied interest in owning and/or operating microgrid infrastructure, the Project Team views hybrid ownership as a simple, effective model that provides benefits to both NYSEG and the SPV.
- Energy produced by the solar arrays will be valued at NYSEG's average supply charge (the utility's cost of electricity, minus transmission and distribution charges).

- The battery storage units will produce revenues from participation in the NYISO frequency regulation market. However, this market is relatively thin and prices are far from stable. For that reason, the Project Team has used conservative assumptions for estimating the value of frequency regulation.
- NYSEG, as the local expert in energy distribution and the current owner and operator of the Town's distribution infrastructure, may operate the microgrid. NYSEG's existing infrastructure is used extensively in the preliminary microgrid design, so operational participation from the utility is vital to the project's success.
- The current regulatory, legal, and policy environment will stay consistent. The proposal outlined in this report falls within the existing frameworks.

The microgrid can enter island mode to participate in DR programs or engage in TOU bill management. However, NYSEG DR programs are not as lucrative as the NYISO frequency regulation market, and achieving effective TOU bill management for the entire microgrid would require nearly continuous operation in island mode. For a discussion of the regulatory issues surrounding extended periods of islanded operation, see the Appendix.

In addition to revenues from electricity sales, the microgrid will provide indirect financial and non-financial benefits to Liberty citizens, SPV shareholders, NYSEG, NYISO and the larger Sullivan County community. Improved energy resilience enhances the local population's safety and quality of life during emergency outages, and local energy generation reduces the strain on the larger energy transmission and distribution infrastructure.

Permitting and regulatory challenges should be reasonably straightforward. The primary regulatory consideration will be the Clean Air Act permitting of the new diesel generator. The SPV will also need to apply for a zoning permit through the Town of Liberty's zoning process for the installation of the proposed DERs.

4. Cost Benefit Analysis

This section is made up of seven sections in addition to the introduction:

- ***Section 1*** analyzes the *facilities connected to the microgrid* and their energy needs.
- ***Section 2*** discusses the *attributes of existing and proposed distributed energy resources*, including factors such as nameplate capacity and expected annual energy production.
- ***Section 3*** analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.
- ***Section 4*** reviews the *overall costs* associated with construction and installation of the microgrid as well as the fuel, operation, and maintenance costs required over the lifetime of the microgrid.
- ***Sections 5 and 6*** discuss the *community benefits* of maintaining power during a grid-wide outage and outline the costs associated with operating the microgrid in island mode.

- ***Section 9*** presents the Industrial Economics (IEc) *benefit-cost analysis report and associated Project Team commentary.*

4.1 Facility and Customer Description (Sub Task 4.1)

The Liberty microgrid will include ten facilities and load clusters from multiple rate classes and economic sectors. There are three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 MWh per year), and large commercial (greater than 50 MWh per year). See Table 24 for basic statistics on each facility's energy usage.

Four of the proposed microgrid facilities belong to the large commercial rate class rate class requiring approximately 1,553 MWh of electricity per year. Two facilities are a part of the small commercial rate class and consume 48 MWh of electricity per year. The remaining four load clusters make up the residential rate class which collectively use 425 MWh. Additionally, the average aggregate demand in 2014 was 0.231 MW and rose as high as 0.504 MW.

There are three kinds of facilities: public, commercial, and residential/other. Facilities belonging to the public sector represent the largest projected electricity loads, comprising more than 53% of the microgrid's total annual electricity usage. The commercial sector facilities make up about 26% of the total electricity usage. The residential/other facilities are approximately 21% microgrid's total annual electricity usage.

During a major power outage, the generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage, but may approach their generation limits if the facilities simultaneously reach peak energy use. In these situations, the backup diesel generator may need to come online to supply additional electricity. Some of the facilities do not operate at full capacity for 24 hours a day. Facilities, such as Liberty Elementary School, will only operate 12 hours per day during grid-connected mode. Some critical facilities that normally operate less than 24 hours per day may need to operate continuously in emergency island-mode situations. For example, the elementary school normally requires electricity for lighting, electrical appliances, and heating/cooling during the daytime hours, but could serve as a community shelter in emergencies. This will extend its electricity usage window from 12 hours per day to 24 hours per day. For information on each facility's average daily operation during a major power outage, see Table 24.

Table 24. Facility and Customer Detail Benefit[41]

Table provides details about each facility and customer served by the microgrid, including average annual electricity usage, 2014 peak electricity demand, and hours of electricity required during a major power outage.

	Facility Name	Rate Class	Facility Description	Economic Sector	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Required Per Day During Major Power Outage[42]
1	Town Government Center	Large Commercial	Local municipal building	Public	81.44	0.023	100%	24
2	Liberty Police Department and Town Office	Large Commercial	Local municipal building, headquarters of Police department	Public	182.00	0.059	100%	24
3	Liberty Public Library	Large Commercial	Local public library	Public	191.10	0.062	100%	~ 8
4	Liberty Elementary School	Large Commercial	Local elementary school for Liberty's students	Public	621.13	0.162	100%	24
5	Sun Gate Mini Mart and Gas Station	Small Commercial	Gas station and convenience store	Commercial	48.00	0.011	100%	~ 12
6	Great American (Supermarket)	Large Commercial	Local supermarket	Commercial	477.36	0.106	100%	24
7	Load Cluster 1	Residential	Set of facilities with three businesses	Residential/ Commercial	32.64 - total 10.88 - per ratepayer	0.011 - total 0.004 - per ratepayer	100%	~ 12

[41] Load data was provided to Booz Allen by NYSEG.
[42] The Booz Allen team estimated these numbers based on the facility's expected function during a power outage. For example, the Police Department will operate continuously to provide safety and emergency management services to the Town.

	Facility Name	Rate Class	Facility Description	Economic Sector	Average Annual Electricity Usage Per Customer (MWh)	Peak Electricity Demand Per Customer (MW)	Percent of Average Usage Microgrid Could Support During Major Power Outage	Hours of Electricity Required Per Day During Major Power Outage[42]
8	Load Cluster 2	Residential	Set of facilities with four residences, one church and one business	Residential/ Religious	240.00 - total 40 - per ratepayer	0.073 - total 0.012 - per ratepayer	100%	~ 12
9	Load Cluster 3	Residential	Set of facilities with five residences, one church and one business	Residential/ Religious	75.60 - total 10.88 - per ratepayer	0.017 - total 0.002 - per ratepayer	100%	~ 12
10	Load Cluster 4	Residential	Set of facilities with two residences and one public building	Residential/ Public	77.00 - total 25.66 - per ratepayer	0.025 - total 0.008 - per ratepayer	100%	~ 12
	Totals	----	**10 Total Facilities**	----	**504.13**	**1.9018**	**100%**	----

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates distributed energy resources, including one existing solar PV array, a proposed diesel generator, two proposed solar PV arrays, and three proposed zinc-air batteries. The combined solar PV arrays will produce an average of 0.094 MW of electricity throughout the year (including projected capacity factors), and the diesel generator at Liberty Elementary School will provide up to 0.2 MW of backup generation capacity during emergencies.

Limited by weather conditions and the availability of sunlight, the combined solar PV arrays are expected to produce a total of 821 MWh per year (assuming a capacity factor of 14%).[43] Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average the solar arrays will produce 2.25 MWh of electricity per day, which represents 41% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar arrays will be around $13,400 per year,[44] which means the marginal cost of producing solar electricity will be about 34/MWh.[45]

The proposed zinc-air batteries will not generate any electricity but will be able to act as a backup source of electricity during emergency situations. Each battery unit is capable of providing up to 1 MW of load supports, well over 100% of the microgrid's average daily demand, for up to four hours.

The proposed backup diesel generator will be used only in islanded situations when the proposed solar arrays or batteries are not producing sufficient electricity to meet aggregate demand when the solar arrays go offline for maintenance. The proposed generator has a nameplate capacity of 0.2 MW. The Booz Allen team forecasts around 1.93 hours of larger grid outage based on NYSEG's CAIDI from 2013,[46] and therefore predicts that annual output from backup diesel generators will be insignificant. The 0.2 MW generator requires around 14.2 gallons of fuel per hour of operation.[47] In the event of a major power outage, the generator could produce up to 4.8 MWh/day—however, assuming that the solar PV arrays will require backup power during 60% of emergency outage hours,[48] this figure drops to 2.88 MWh/day. See Table 25 for a detailed list of all proposed and existing distributed energy resources in Liberty.

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43 Solar array capacity factor: 14% (NREL PV Watts Calculator).

44 Annual fixed O&M cost: $20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).

45 Capital cost: $2,400 – $2,700 (Siemens estimate for solar array), Variable cost: 20 years of production at a cost of $20/kW per year (Siemens lifecycle estimate, NREL), Discount rate: 7% (industry standard discount rate; NREL http://www.nrel.gov/docs/fy13osti/58315.pdf).

46 Grid outage data from DPS 2013 Electric Reliability Performance Report (NYSEG average CAIDI).

47 Backup Diesel Generator fuel consumption rate – 14.2 gallons/hour (Cummins Power Generation).

48 The Booz Allen team forecasts a 60% level of operation from the backup generator based on historical loads and expected generator output. In 2014, the average load in Liberty was 0.231 MW. Load is expected to exceed the solar PV arrays' maximum output for approximately 60% of time spent in island mode. Solar output is unreliable, but it should provide significant support on the most irradiated days of the year when peak demand is highest.

Table 55. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs). "Normal operating conditions" assumes approximately 1.93 effective hours of operation per year for the diesel backup generator.

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Expected Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER1 - Solar PV array	Liberty Elementary School	Sun Light	0.07	85.85	0.24	0.56[49]	N/A	N/A
DER2 - Roof-top solar PV array	Liberty Elementary School	Sun Light	0.15	183.96	0.5	1.2[50]	N/A	N/A
DER3 - Diesel backup generator	Liberty Elementary School	Diesel	0.2	1.2	0.0033	4.8	71 Gallons	9.86 MMBTUs
DER4 - Carport solar PV array	Liberty Elementary School	Sun Light	0.45	551.88	1.51	3.6[51]	N/A	N/A
DER5 - Zinc air battery unit	Liberty Elementary School	N/A	1 MW/4 MWh	N/A	4.0	4.0	N/A	N/A
DER6 - Zinc air battery unit	Liberty Elementary School	N/A	1 MW/4 MWh	N/A	4.0	4.0	N/A	N/A
DER6 - Zinc air battery unit	Liberty Elementary School	N/A	1 MW/4 MWh	N/A	4.0	4.0	N/A	N/A

[49] Assumes 10 hours of production (daylight) at 80% of capacity.
[50] Assumes 10 hours of production (daylight) at 80% of capacity.
[51] Assumes 10 hours of production (daylight) at 80% of capacity.

4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3)

4.3.1 Peak Load Support

The microgrid's proposed generation assets will operate nearly continuously throughout the year, providing a constant level of load support.

The proposed solar arrays will be at their most productive on the most irradiated days of year when peak demand events are common, thus providing peak load support when it is most needed. The solar PV arrays will provide around 0.0938 MW of load support on average over the course of a year. However, because its generation depends on weather conditions and time of day, the solar arrays are not a reliable source of peak load support.

The proposed zinc air batteries will also be able to provide peak load support. Each battery unit will have the ability to provide up to 1 MW of load support for 4 hours at full charge.

See Table 26 for the maximum generation capacities of the proposed and existing DERs.

Table 26. Distributed Energy Resource Peak Load Support

Table shows the available capacity and impact of the expected provision of peak load support from each DER. Existing generator was not included because it is not expected to generate electricity outside of emergency island mode situations.

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER1 - Solar PV array	Liberty Elementary School	Maximum of 0.07	Yes
DER3 - Roof-top solar PV array	Liberty Elementary School	Maximum of 0.15	No
DER4 - Carport solar PV array	Liberty Elementary School	Maximum of 0.45	No
DER5 - Zinc air battery unit	Liberty Elementary School	1.0	No
DER6 - Zinc air battery unit	Liberty Elementary School	1.0	No
DER7 - Zinc air battery unit	Liberty Elementary School	1.0	No

4.3.2 Deferral of Transmission/Distribution Requirements

NYSEG's grid is congested in the Liberty area, however it is not known if this project will directly impact the distribution lines affected, therefore the 0.0938 MW of average local generation produced by the DERs will only marginally defer the need to invest in new or upgraded power lines. Although these power lines will last up to one hundred years if well maintained,[52] they can only transmit a limited amount of power. As demand for electricity in Liberty increases, the lines might need to be supplemented to handle additional load.

The same is true for distribution capacity investments on a local, feeder-by-feeder basis. However, constructing DERs could actually increase the distribution capacity investment cost in certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to

[52] Professor John Kassakian, MIT: http://engineering.mit.edu/ask/how-do-electricity-transmission-lines-withstand-lifetime-exposure-elements.

the local grid). Liberty has ample capacity within the town, construction of DERs will not require a significant distribution capacity investment.

4.3.3 Ancillary Service

The proposed zinc air batteries in the Liberty microgrid will participate in ancillary services markets. Each zinc air battery unit will bid 1 MW of capacity into the NYISO frequency regulation market throughout the year. By continuously discharging or charging according to signals from the NYISO, the batteries will produce revenues for owners and improve power stability on the larger grid.

4.3.4 Development of a Combined Heat and Power System

Due to lack of natural gas pipelines in the area and lack of thermal off-takers within a technically feasible distance of the generation site, the Project Team decided to propose solar PV arrays and zinc air batteries instead of a CHP unit. Therefore, there is no proposed CHP unit for the Liberty microgrid.

4.3.5 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 298 $MTCO_2e$ (metric tons CO_2 equivalent) decrease in GHG emissions in Liberty as compared to the New York State energy asset mix. The proposed generation assets will produce around 823 MWh of electricity per year. The backup diesel generator will emit approximately 1 $MTCO_2e$ per year, while the solar arrays will emit none. The current New York State energy asset mix would emit approximately 299 $MTCO_2e$ to produce the same amount of electricity[53]. The microgrid's generation assets will therefore result in a net decrease in emissions by 298 $MTCO_2e$.

The microgrid's generation assets will not need to purchase emissions permits to operate and will not exceed current New York State emissions limits for generators of their size. The New York State overall emissions limit was 64.3 $MMTCO_2e$ in 2014, and will begin decreasing in the near future. The state sells an "allowance" for each ton of CO_2e emitted in excess of the limit at allowance auctions, but does not require assets under 25 MW to purchase allowances.

Table 27 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) emissions rates for the diesel generators.

[53] Assuming an asset mix of 15% coal, 31% natural gas, 6% oil, 17% hydro, 29% nuclear, 1 % wind, 1% sustainably managed biomass, and 1% "other fuel". This adds up to around 0.36 $MTCO_2e$/MWh. Info from EPA (http://www3.epa.gov/statelocalclimate/documents/pdf/background_paper_3-31-2011.pdf).

Table 27. Emission Rates

Table shows the emission rates for each DER per MWh and per year. Notice the rates vary drastically for each emissions type (CO_2, SO_2, NO_x).

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER3 – Backup Diesel Generator	Liberty Elementary School	CO_2	0.7196[54]
		SO_2	0.1911[55]
		NO_x	2.9074[56]
		PM	0.2046[57]

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

The microgrid design requires the following new pieces of equipment at the substation and across the rest of the microgrid:

- A control system to provide one point of control for operating the microgrid and synthesizing real-time electricity data from the connected facilities.
- Intelligent Electronic Devices to interface with the 44 kilovolt (kV) utility breaker at the substation as well as the smaller 4.8 kV distribution feeders.
- Automated breakers installed throughout Liberty to allow the microgrid to isolate and maintain power to the microgrid connected facilities.
- Grid-paralleling switchgear to synchronize each generator's output to the system's frequency.

The total installed capital cost of the distributed equipment is estimated to be $503,500 and $12,000 for the IT infrastructure. The Project Team estimates the 0.15 MW solar PV array, 0.45 MW solar PV array, 0.2 MW diesel generator, and three zinc air battery units carry an installed cost of $360,000, $1.21 million, $200,000 and $2.5 million, respectively.[58] This brings the total installed capital cost to approximately $4.79 million, not including interconnection fees and site surveys. Additionally the estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the microgrid. See Tables 28 and 29 below for estimated installed costs for each microgrid component.

[54] **Diesel Generator Emissions rate**: 0.72 $MTCO_2e$/MWh (assuming 161 lb CO_2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).
[55] Michigan Department of Environmental Quality; Environmental Science and Services Division. "Potential to Emit, Diesel Fired Generator Calculation Worksheet."
[56] Ibid.
[57] Ibid.
[58] Diesel Generator Capital Cost: $1,000/kW (Siemens Diesel estimate).
Solar PV Capital Cost: $2,400 - $2,700/kw (Siemens Solar PV estimate).

The Project Team estimates nearly every piece of microgrid equipment has a useful lifespan of 20 years. The only component with a shorter lifespan will be the microgrid control system (Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after 7-8 years.

Table 28 details capital cost of the substation. The substation includes equipment such as the microgrid control system and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

Table 28. Distributed Equipment Capital Cost

Table displays the estimated costs and lifespan of the distributed equipment associated with the microgrid.

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System	1 Primary	$50,000 (total)	7 - 8	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
(Siemens SICAM PAS or equivalent)	1 Back-up			
Microgrid Control Center (Siemens MGMS or equivalent)	1	$300,000	20	Provides data trending, forecasting, and advanced control of generation, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch.
Automated, Pole-mounted Circuit Breaker/Switches (Siemens 7SC80 relay or equivalent)	2 new 2 upgrade	$50,000 $10,000	20	New relays/controllers at pole mounted distribution switches/breakers. These components will disconnect the microgrid from the Liberty 145 feeder and can shed loads 3, 5, 6, 7, and 8. Components include Synchro check capability.
Generation Controls (OEM CAT, Cummins, etc.)	1	$4,000	20	OEM Generation controllers serve as the primary resource for coordinating diesel generator ramp up/ramp down based on external commands and reaction to Microgrid load changes
PV Inverter Controller (OEM Fronius or equivalent)	3	$12,000	20	These components control PV output and send live solar/power output data to SCADA and EMS for forecasting/decision making input

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/- 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Storage Inverter Controller (OEM Fronius or equivalent)	3	$12,000	20	These components control battery storage input/output and send live power data to SCADA and EMS for forecasting. They receive charge/discharge commands from SCADA Microgrid control.
WiMax Base Station	1	$8,000	20	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	4	$8,000	20	Each subscriber unit can communicate back to the WiMax base station for SCADA monitoring and control or remote relay to relay GOOSE messaging.
WiMax configuration and testing	1	$23,000	-	The configuration and testing of the WiMax hardware
Installation Costs	1	$26,500	-	Installation of capital components in the microgrid

Table 29. Capital Cost of Proposed Generation Units

Table displays the estimated costs and lifespan of the equipment associated with the generation units of the microgrid.

Proposed Generation Units				
Capital Component	Quantity	Installed Cost ($) (+/- 30%)	Component Lifespan (Years)	Purpose/Functionality
0.15 MW PV System	1	$360,000	30	Generation of electricity
0.45 MW PV System	1	$1,215,000	30	Generation of electricity
1 MW / 4 MWh zinc air battery unit	1	$832,000	20	Storage of electricity
1 MW / 4 MWh zinc air battery unit	1	$832,000	20	Storage of electricity
1 MW / 4 MWh zinc air battery unit	1	$832,000	20	Storage of electricity
0.2 MW Backup Diesel Generator	1	$200,000	20	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet cables for communication between distribution switches, generation switchgear, PV inverters, and network switches. The design uses Cat-5e cabling, including RJ-45 connectors at $0.61 per cable.[59] The total installation cost of cabling is approximately $5.65 per foot.[60] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines. The estimated total cost for the microgrid IT infrastructure is around $12,000.[61]

4.4.2 Initial Planning and Design Cost

The initial planning and design of the microgrid includes four preparation activities and total to approximately $750,000.

1. The first set of activities are the design considerations and simulation analysis which will cost approximately $575,000 to complete.
2. The second activity focuses on the financial aspects of the project including project valuation and investment planning which will cost approximately $75,000.
3. The third activity focuses on the legal aspects of the project including an assessment of regulatory issues and legal viability which will cost approximately $50,000.

[59] Commercially available RJ-45 connectors, $0.30 per connector.
[60] Installation costs for Cat5e: $5.45/ft. Component cost for Cat5e: $0.14/ft (commercially available).
[61] The Project Team estimated ~2,000 feet of Cat5e will be necessary.

4. The fourth activity focuses on the development of contractual relationships with key partners will cost approximately $50,000.

A breakout of the initial planning and design costs are illustrated in Table 30 below.

Table 30. Initial Planning and Design Cost

Table displays estimates and descriptions for engineering, legal, and financing costs involved in initial planning and design of the microgrid.

Initial Planning and Design Costs ($)[62]	Cost Components
$575,000	Design considerations and simulation analysis
$75,000	Project valuation and investment planning
$50,000	Assessment of regulatory, legal, and financial viability
$50,000	Development of contractual relationships
$750,000	**Total Planning and Design Costs**

4.4.3 Operations and Maintenance Cost

The proposed DERs will incur fixed operation and maintenance costs, including fixed annual service contracts.

The microgrid owner will also incur $75,000 per year in total costs for annual fixed system service agreements for the zinc air battery unit. Additionally the total costs for annual fixed system service agreements for the solar PV arrays and backup diesel generator will be approximately $14,320 per year. [63]

The diesel fuel usage of the backup diesel generators is difficult to predict because they will be used only during some emergency outage situations. The average price of diesel fuel in New York State from 2013-2015 was $3.91 per gallon, which translates to an average fuel cost of approximately $25/MWh. The high price of diesel fuel, along with increased GHG emissions, discourages extended use of the diesel generators.

The solar PV arrays will not require fuel to operate, and should not require service outside of the normally scheduled downtime. Normally scheduled downtime should cost approximately $20/kW per year.[64]

[62] Estimates developed by Booz Allen Project Team and independent consultant.
[63] $75,000 for zinc air battery unit ($25/kw per year), $13,400 for solar PV arrays ($20/kW per year) and $4.60/kW per year for backup diesel generators (Electric Power Research Institute, "Costs of Utility Distributed Generators, 1-10 MW").
[64] NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[65] Table 31 outlines all fixed operations and maintenance (O&M) costs associated with normal operation of the DERs.

Table 31. Fixed Operating and Maintenance Cost

Table displays estimated values and descriptions of the fixed O&M costs associated with operating and maintaining the microgrid's DERs.

Fixed O&M Costs ($/year)	Cost Components
~ $13,400 (total)	Solar PV System Service Agreement – Annual costs of maintenance and servicing of units
~$920	Diesel Generator Service Agreement – Annual costs of maintenance and servicing of unit
$75,000	Battery System Service Agreement – Annual costs of maintenance and servicing of units
$70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

4.4.4 Distributed Energy Resource Replenishing Fuel Time

At full operation, the proposed 0.2 MW diesel generator will require 14.2 gallons of diesel fuel per hour at full load. The proposed diesel generator has a 340 gallon diesel storage tank installed, so at a 100% level of output this generator can operate for 24 hours without replenishing its fuel supply. Cutting output to 50% increases the maximum operation time to 48 hours.

The solar PV arrays do not require fuel for operation, but their output depends on weather and time of day.

The zinc air batteries does not require fuel for operation, but are limited by a maximum output of 1 MW for a total of 4 hours each. Table 32 shows the fuel consumption and operating times for all of the microgrid DERs.

[65] O&M for non-DER microgrid components: $70,000/year (Siemens).

Table 32. Maximum Fuel Operating Time for Distributed Energy Resource

Table displays the potential maximum operating times in Islanded Mode for each DER. The corresponding fuel consumption for each DER is also detailed.

Distributed Energy Resource	Location	Energy Source	Maximum Operating Time in Islanded Mode without Replenishing Fuel (hours)	Fuel Consumption During this Period	
				Quantity	Unit
DER1 - Solar PV array	Liberty Elementary School	Sun Light	N/A	N/A	N/A
DER2 - Roof-top solar PV array	Liberty Elementary School	Sun Light	N/A	N/A	N/A
DER3 - Diesel backup generator	Liberty Elementary School	Diesel	24	~ 340	Gallons
DER4 - Carport solar PV array	Liberty Elementary School	Sun Light	N/A	N/A	N/A
DER5 - Zinc air battery unit	Liberty Elementary School	N/A	4 (at 1 MW load)	N/A	N/A
DER6 - Zinc air battery unit	Liberty Elementary School	N/A	4 (at 1 MW load)	N/A	N/A
DER6 - Zinc air battery unit	Liberty Elementary School	N/A	4 (at 1 MW load)	N/A	N/A

4.5 Costs to Maintain Service during a Power Outage (Sub Task 4.5)

4.5.1 Backup Generation Cost during a Power Outage

All microgrid generation assets will serve as backup generators in the event of an extended power outage. The solar arrays will be available for generation during a power outage, but their production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when high state-wide electricity demand on the most irradiated days of summer causes outages, the solar panels will be at their most productive and could provide up to 0.0938 MW of load support to the Liberty microgrid.

The zinc air batteries will be able to provide backup load support to the microgrid in the case of a grid wide outage. Each zinc air battery can provide up to 1 MW for 4 hours at full charge. This level of energy storage should provide sufficient power to the microgrid connected facilities during an outage.

The backup diesel generators will only come online when the solar arrays and zinc air batteries do not provide sufficient power to the islanded microgrid. Because the solar arrays and zinc air can produce 3.09 MW of power at full capacity and the microgrid's loads had an average power demand of 0.231 MW during 2014, the zinc air batteries and solar arrays should be capable of satisfying the microgrid's power demand in most situations. The diesel generator will only be necessary for about 60% of total outage time. At 60% operation the 0.2 MW diesel generator would produce an average of 2.88 MWh per day. The backup generator will require around 205 gallons of fuel per day at this level of generation. One-time startup costs or daily non-fuel maintenance costs for either of the diesel generators are not anticipated.

Table 33 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

Table 33. Cost of Generation during a Power Outage

Table lists each generation unit and its respective energy source. Additionally, nameplate capacity, expected power outage operating capacity, and daily average production of power (in MWh) is detailed. Lastly quantity and units of daily fuel and operating costs (both one-time and ongoing) are described.

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4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for Table 33. Please refer to Table 33 for one-time and ongoing costs of microgrid generation per day. The proposed microgrid has the capacity to support all the connected facilities, which means even those facilities with backup generators will not have to rely on or pay for on-site backup power. Facilities not connected to the microgrid will experience power outages and may need emergency services depending on the severity of the emergency event. Any other cost incurred during a wide spread power outage will be related to the emergency power (i.e. portable generators) rather than electricity generation costs.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

Most of the facilities to be connected to the microgrid are municipally owned buildings that serve the entirety of the population in Liberty (such as the Town Center and Police Department). Others, like the Liberty Elementary School, serve a smaller population for most of the year, but provide critical services to the entire population during emergency situations. For estimates of the population served by each critical facility, see Table 34.

Backup power supplied by the microgrid should provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g. driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g. receiving a 911 call or local water sanitizing operations). Based on the portfolio of services that each facility provides and the electricity dependency of each service, Table 34 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 34. Critical Services Supported

Table details critical services supported by the microgrid during an outage. The table also shows the percentage of services lost for each facility when backup power is not available during an outage.

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage[66]	
		When Backup Power is Available	When Backup Power is Not Available
Town Government Center	4,200	0%	> 50%
Liberty Police Department and Town Office	4,200	0%	> 50%
Liberty Public Library	4,200	0%	> 75%
Liberty Elementary School	~ 250	0%	> 75%
Sun Gate Mini Mart and Gas Station	4,200	0%	> 75%
Great American (Supermarket)	4,200	0%	> 90%
Load Cluster 1	~ 15	0%	> 75%
Load Cluster 2	~ 125	0%	> 50%
Load Cluster 3	~ 130	0%	> 50%
Load Cluster 4	~ 14	0%	> 75%

4.7 Industrial Economics Benefit-Cost Analysis Report

As follows is a direct cost-benefit analysis deliverable from Industrial Economics. IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-cost analysis of the Liberty microgrid was delivered to the Project Team on March 24, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the Village of Liberty has proposed development of a microgrid that would serve 25 facilities within the Village: six individual facilities and four load clusters. These facilities include:

- The Town Government Center;
- The Liberty Police Department and Village Office;
- Liberty Public Library;
- Liberty Elementary School;
- Sun Gate Mini Mart and Gas Station;

[66] Booz Allen estimated % loss based on energy demands and services provided for Emergency Services, Municipal Services, Health Services, and Education Services based on previous research by NIH and CDC (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1497795/; http://www.ncbi.nlm.nih.gov/pubmed/15898487; http://emergency.cdc.gov/disasters/poweroutage/needtoknow.asp).

- A Great American Supermarket;
- Load Cluster 1, which includes three small commercial businesses;
- Load Cluster 2, which includes four residential facilities and two small commercial facilities (one church and one business);
- Load Cluster 3, which includes five residences and two small commercial facilities (one church and one business); and
- Load Cluster 4, which includes two residences and one public building.

The microgrid would be powered by seven new distributed energy resources: three photovoltaic arrays (0.07 MW, 0.15 MW, and 0.45 MW); one 0.2 MW backup diesel generator; and three Eos Aurora battery units, each with a 1.0 MW output and 4.0 MWh of storage. All seven distributed energy resources would be located at the Liberty Elementary School. The village anticipates that the photovoltaic systems would produce electricity for the grid during periods of normal operation. In contrast, the diesel generator and battery units would produce power only during an outage, when the microgrid would operate in islanded mode. The system as designed would have sufficient generating capacity to meet average demand for electricity from all facilities on the microgrid circuit during a major outage.

To assist with completion of the project's NY Prize Stage 1 feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis, which is based on the methodology outlined below.

4.7.2 Methodology and Assumptions

In discussing the economic viability of microgrids, a common understanding of the basic concepts of benefit-cost analysis is essential. Chief among these are the following:

- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- *Benefits* are impacts that have value to a firm, a household, or society in general.
- *Net benefits* are the difference between a project's benefits and costs.
- Both costs and benefits must be measured relative to a common *baseline* - for a microgrid, the "without project" scenario - that describes the conditions that would prevail absent a project's development. The BCA considers only those costs and benefits that are *incremental* to the baseline.

This analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the costs and benefits of developing microgrids in New York State. The model evaluates the economic viability of a microgrid based on the user's specification of project costs, the project's design and operating characteristics, and the facilities and services the project is designed to support. Of note, the model analyzes a discrete operating scenario specified by the user; it does not identify an optimal project design or operating strategy.

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[67] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

With respect to public expenditures, the model's purpose is to ensure that decisions to invest resources in a particular project are cost-effective; i.e., that the benefits of the investment to society will exceed its costs. Accordingly, the model examines impacts from the perspective of society as a whole and does not identify the distribution of costs and benefits among individual stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple projects, the "societal cost test" guides the decision toward the investment that produces the greatest net benefit.

The BCA considers costs and benefits for two scenarios:

- Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).
- Scenario 2: The average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[68]

[67] The seven percent discount rate is consistent with the U.S. Office of Management and Budget's current estimate of the opportunity cost of capital for private investments. One exception to the use of this rate is the calculation of environmental damages. Following the New York Public Service Commission's (PSC) guidance for benefit-cost analysis, the model relies on temporal projections of the social cost of carbon (SCC), which were developed by the U.S. Environmental Protection Agency (EPA) using a three percent discount rate, to value CO_2 emissions. As the PSC notes, "The SCC is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO_2, NO_x, and $PM_{2.5}$, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

[68] The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents;

4.7.3 Results

Table 35 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 9.4 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 35. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Expected Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 9.4 Days/Year
Net Benefits - Present Value	-$3,540,000	$13,500
Benefit-Cost Ratio	0.5	1.0
Internal Rate of Return	-3.9%	6.7%

<u>Scenario 1</u>

Figure 6 and Table 36 present the detailed results of the Scenario 1 analysis.

prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

Figure 6. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

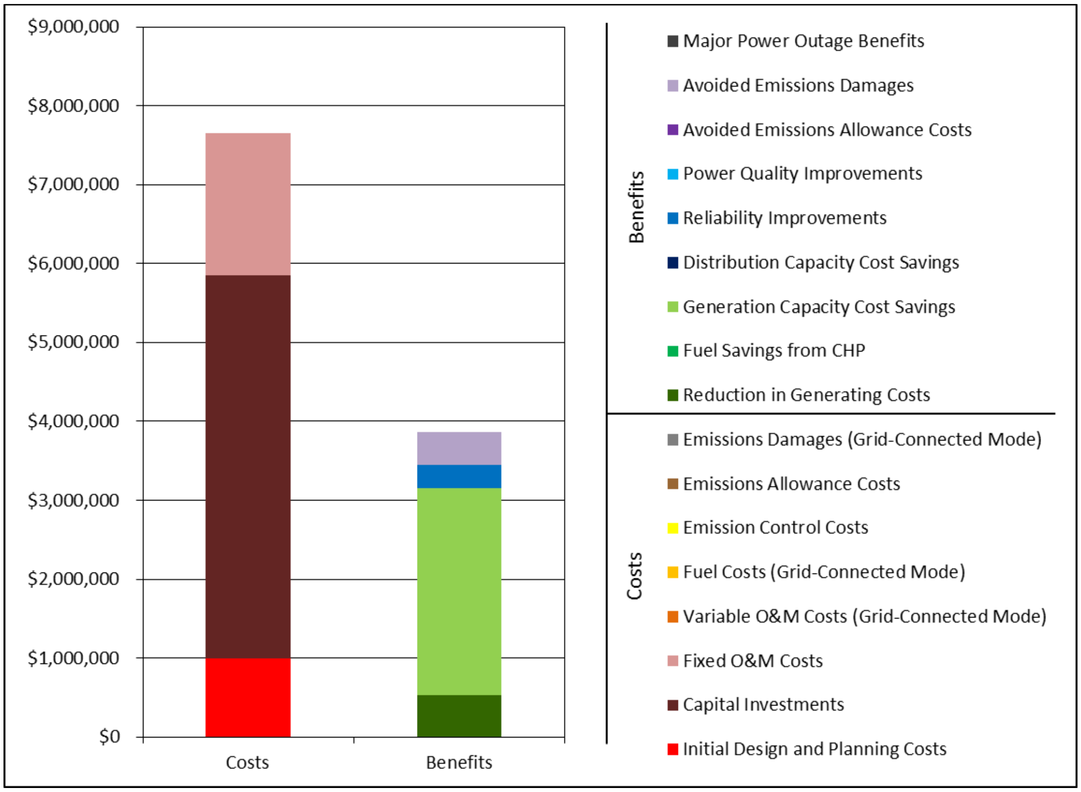

Table 36. Detailed BCA Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$750,000	$66,200
Capital Investments	$4,850,000	$427,000
Fixed O&M	$1,800,000	$159,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$0	$0
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$0	$0
Total Costs	**$7,400,000**	
Benefits		
Reduction in Generating Costs	$532,000	$47,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$2,620,000	$231,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$296,000	$26,100
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$279	$25
Avoided Emissions Damages	$414,000	$27,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$3,870,000**	
Net Benefits	**-$3,540,000**	
Benefit/Cost Ratio	**0.5**	
Internal Rate of Return	**-3.9%**	

Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $750,000. The present value of the project's capital costs is estimated at approximately $4.9 million, including costs associated with installing a microgrid control system; equipment for the substation that would be used to manage the microgrid; the IT infrastructure (communication cabling) for the microgrid; and the new distributed energy resources. Operation and maintenance (O&M) of the entire system would be provided under fixed price service agreements, at an estimated annual cost of $159,000. The present value of these O&M costs over a 20-year operating period is approximately $1.8 million.

Variable Costs

The Project Team does not anticipate any variable costs associated with Liberty's proposed microgrid project during periods of normal operation. Any variable costs would be limited to those associated with the operation of the diesel generator during an outage.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. In the case of the Village of Liberty's proposed microgrid, the BCA estimates a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs of approximately $0.5 million over a 20-year period; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers would also avoid emissions of CO_2, SO_2, NO_x, and particulate matter, yielding emissions allowance cost savings with a present value of approximately $300 and avoided emissions damages with a present value of approximately $414,000.[69]

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[70] Based primarily on the capacity of the battery units, as well as standard capacity factors for solar power, the Project Team estimates the project's impact on demand for generating capacity to be approximately 3.1 MW per year (the team estimates no impact on distribution capacity). On the basis of this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $2.6 million over a 20-year operating period. [71]

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $26,000 per year, with a present value of approximately $300,000 over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[72]

- System Average Interruption Frequency Index – 1.03 events per year

[69] Following the New York Public Service Commission's guidance for benefit cost analysis, the model values emissions of CO_2 using the social cost of carbon (SCC) developed by the U.S. Environmental Protection Agency. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.] Because emissions of SO_2 and NO_x from bulk energy suppliers are capped and subject to emissions allowance requirements in New York, the model values these emissions based on projected allowance prices for each pollutant.

[70] Impacts on transmission capacity are implicitly incorporated into the model's estimates of avoided generation costs and generation capacity cost savings. As estimated by NYISO, generation costs and generating capacity costs vary by location to reflect costs imposed by location-specific transmission constraints.

[71] The estimate of generating capacity benefits assumes utilization of the batteries in grid-connected mode to produce power during periods of peak demand. If the batteries are used solely as a source of power during outages, the project's impact on generating capacity requirements – and any associated cost savings – would be negligible.

[72] www.icecalculator.com.

- Customer Average Interruption Duration Index – 118.2 minutes[73]

The estimate takes into account the number of small and large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the Project Team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[74] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

It is important to note that the analysis of reliability benefits assumes that development of a microgrid would insulate the facilities the project would serve from outages of the type captured in SAIFI and CAIDI values. The distribution network within the microgrid is unlikely to be wholly invulnerable to such interruptions in service. All else equal, this assumption will lead the BCA to overstate the reliability benefits the project would provide.

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.5; i.e., the estimate of project benefits is approximately half of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2

Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[75,76]

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[73] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for New York State Electric & Gas.

[74] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

[75] The methodology used to estimate the value of lost services was developed by the Federal Emergency Management Agency (FEMA) for use in administering its Hazard Mitigation Grant Program. See: FEMA Benefit-Cost Analysis Re-Engineering (BCAR): Development of Standard Economic Values, Version 4.0. May 2011.

[76] As with the analysis of reliability benefits, the analysis of major power outage benefits assumes that development of a microgrid would insulate the facilities the project would serve from all outages. The distribution network within the microgrid is unlikely to be wholly invulnerable to service interruptions. All else equal, this will lead the BCA to overstate the benefits the project would provide.

As noted above, the Village of Liberty's microgrid project would serve a number of commercial and residential facilities. The project's consultants indicate that at present, none of the facilities are equipped with backup generators. In the event of an outage, each facility could maintain 100 percent of service capabilities by bringing in portable generators; Table 37 lists the associated costs. In the absence of backup power – i.e., if the backup generators failed and no replacements were available – all the facilities would experience between 50 and 90 percent losses in service capabilities (see Table 37).

Table 37. Backup Power Costs and Level of Service, Scenario 2

Facility Name	Cost of Maintaining Service with Portable Generator ($/Day)	Percent Loss in Service When Backup Generation is Not Available
Town Government Center	$625	50%
Liberty Police Department and Village Office	$1,119	50%
Liberty Public Library	$1,119	75%
Liberty Elementary School	$1,672	75%
Sun Gate Mini Mart and Gas Station	$314	75%
Great American (Supermarket)	$1,269	90%
Load Cluster 1	$314	75%
Load Cluster 2	$1,119	50%
Load Cluster 3	$352	50%
Load Cluster 4	$625	75%

The information provided above serves as a baseline for evaluating the benefits of developing a microgrid. Specifically, the assessment of Scenario 2 makes the following assumptions to characterize the impacts of a major power outage in the absence of a microgrid:

- All of the facilities would rely on portable generators, experiencing no loss in service capabilities while the units are in operation. If the portable generators fail, the facilities would experience a loss in service capabilities of between 50 and 90 percent.
- In all cases, the supply of fuel necessary to operate backup generators would be maintained indefinitely.
- At each facility, there is a 15 percent chance that the backup generator would fail.

The economic consequences of a major power outage also depend on the services the facilities of interest provide. The analysis varies by facility, as described below:

- For police services, the analysis calculates the impact of a loss in service using standard FEMA values for the costs of crime, the baseline incidence of crime per capita, and the impact of changes in service effectiveness on crime rates.
- For residential facilities, the analysis assumes that the residents being served would be left without power; the impact is valued as a social welfare loss.

- For the Liberty Elementary School, the value of service is estimated at approximately $51,000 per day. This figure is based on the school district's budget for the 2015-2016 school year, scaled by enrollment and pro-rated to an average daily value.[77]
- For the remaining facilities, the value of service is estimated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, based on assumptions about the number of hours of service the facility would require from the microgrid each day during an outage:[78]
  - For the Town Government Center and Great American combined, the value of service is estimated at approximately $108,000 per day, assuming 24 hours of service per day
  - For the Public Library, the value of service is estimated at approximately $14,000 per day, assuming 8 hours of service per day
  - For the Sun Gate Mini Mart and Gas Station, the value of service is estimated at approximately $7,000 per day, assuming 12 hours of service per day
  - For all the commercial facilities included in Load Clusters 1 through 4 combined, the value of service is estimated at approximately $51,000 per day, assuming 12 hours of service per day

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for all facilities is approximately $33,300 per day.

Summary

Figure 7 and Table 38 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 9.4 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

[77] Liberty Central School District, 2015-2016 Budget Information. Accessed March 21, 2016. http://www.libertyk12.org/Budget/2015-16budgetarchive.cfm. Note that this value is at best a rough approximation of the social welfare loss attributable to a loss of power at the school, as it does not account for the potential to reschedule lost school days when power is restored; the impact of disruptions in schedule on the productivity of teachers, school administrators, or children's caregivers; the effect of an extended outage on the cost of operating and maintaining the school; and other factors that would more accurately characterize the impact of a loss of service during an extended outage.

[78] http://icecalculator.com/.

Figure 7. Present Value Results, Scenario 2

(Major Power Outages Averaging 9.4 Days/Year; 7 Percent Discount Rate)

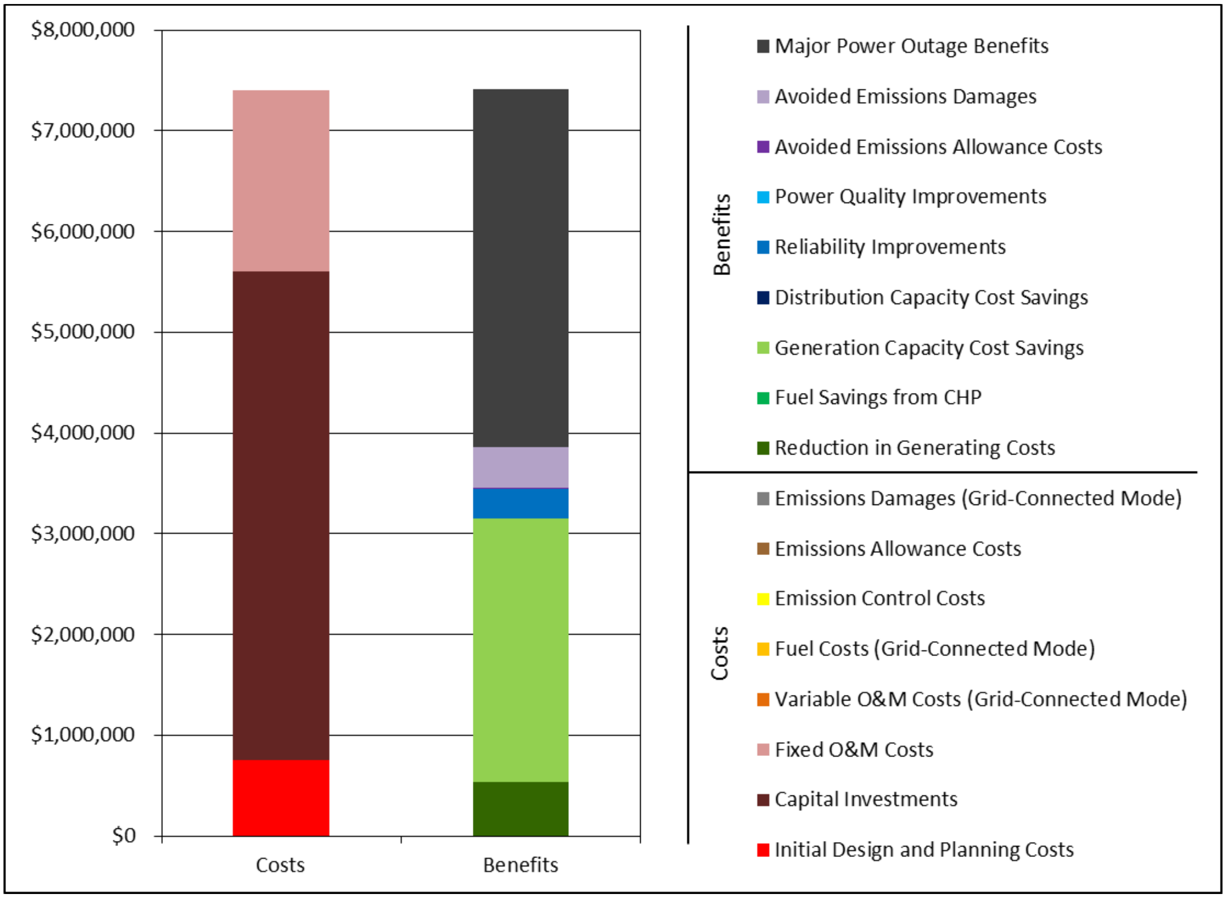

Table 38. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 9.4 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$750,000	$66,200
Capital Investments	$4,850,000	$427,000
Fixed O&M	$1,800,000	$159,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$0	$0
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$0	$0
Total Costs	**$7,400,000**	
Benefits		
Reduction in Generating Costs	$532,000	$47,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$2,620,000	$231,000
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$296,000	$26,100
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$279	$25
Avoided Emissions Damages	$414,000	$27,000
Major Power Outage Benefits	$3,550,000	$313,000
Total Benefits	**$7,420,000**	
Net Benefits	**$13,500**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**6.7%**	

The Project Team assumed an electricity sales price of $0.061 per kWh in Liberty. This is the supply cost for NYSEG, the average amount spent by NYSEG to import electricity into their distribution system. On a long term, fixed volume PPA, the Project Team believes this to be the most accurate pricing model. Industrial Economics modeled the LBMP for the local NYISO zone to price electricity sales. The LBMP is effectively the average spot market price, peaking on summer afternoons and dropping to nearly zero in low demand hours. While the LBMP would be an appropriate price for intermittent and unreliable grid sales, the proposal herein supports reliable, continuous electricity injections into the NYSEG grid. In Liberty, the Mohawk Valley LBMP is $33.63 per MWh[79], or $0.034 per kWh, a more than 44% reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

[79] Average according to IEc cost-benefit model.

5. Summary and Conclusions

5.1 Lessons Learned and Areas for Improvement

The lessons learned from the Liberty microgrid feasibility study are divided into two parts. The first part in Section 5.1.1 highlights Liberty-specific issues to be addressed moving forward. The second part in Sections 5.1.2 and 5.1.3 addresses statewide issues, replicability, and the perspectives of many stakeholder groups. These lessons learned may be generalized and applied across the State and NY Prize communities.

5.1.1 Liberty Lessons Learned

Through the Liberty microgrid feasibility study, the Project Team learned site-specific lessons applicable to other communities in its portfolio and around the state.

Liberty has an attractive footprint for a community microgrid with several critical and important facilities on the end of a single feeder. Electrically, this is an ideal layout that allows for economic islanding without the prospect of disconnecting downstream loads and it provides the basis for fully behind the meter microgrid operation when State regulations and policies surrounding microgrids allow it. Moreover, the particular mix of facilities within the Liberty footprint provide an exceptionally diverse set of community services including shelter, governance, public safety, food, and gasoline. However, the financially feasible development of a microgrid in Liberty is constrained by two important factors, the lack of natural gas availability and the small facility loads.

The lack of natural gas restricts the available energy options to solar, storage, and diesel. Solar is an excellent resource that reduces demand on the grid and brings down energy costs for many, however it is poor baseload for a microgrid given the intermittency and unpredictability. With a capacity factor of approximately 14% in Liberty, any solar array would have to be an order of magnitude larger than the aggregate loads to approach sufficient size to support an islanded grid. No matter the size of the solar, it must be paired with storage, as the Project Team has proposed. Solar does not produce electricity in the dark, overnight hours and storage is the only way to retain daytime generation for night time use. Unfortunately, though there are technically efficient storage solutions, they are rarely cost efficient. Electricity is simply not costly enough in Liberty to justify the investment in battery storage, and alternative revenue streams to support batteries, such as demand response and frequency regulation, do not offer sufficient payments to recover battery costs.

Compounding the resource constraints are the relatively small loads on the Liberty microgrid. Even with more cost efficient and dependable natural gas-fired generation, the loads on the Liberty microgrid are on the cusp of what is typically financially viable. Continuous duty natural gas engines will nearly always cover their own costs with a small amount of profit, however they need to be of a certain scale to return sufficient revenue to subsidize the cost of the microgrid controls and infrastructure upgrades. The result is generating assets that can create sufficient revenue to account for their own operating and capital costs, but owing to the small size, do not produce enough excess revenue to pay for the microgrid costs. This is a consideration not only for Liberty but for many other communities around the state that have smaller loads but still require control infrastructure and software. If natural gas became available in Liberty, an expansion along the existing feeder may allow for the inclusion of sufficient loads to support a financially viable microgrid implementation.

In comparison to working with a municipal utility, working with the investor-owned NYSEG was a more time-intensive process. As a utility with a large footprint, customer base, and T&D network, NYSEG has many issues to manage that require its attention, among which microgrids and NY Prize were just one. NYSEG allowed the inclusion of their feeder and distribution lines in the microgrid design. The result is a technically feasible microgrid that meets NYSERDAs critical facility requirements. A NY Prize Phase II award would require more extensive conversations with NYSEG about their role in a future microgrid on the proposed footprint and how a microgrid might utilize existing infrastructure absent direct involvement of the utility.

5.1.2 Statewide Replicability and Lessons Learned

Through the process of developing deliverables for multiple communities over several months, the Team has discovered and considered new questions surrounding microgrid development. These questions address technical viability, financial structures, policy considerations, and other constraints that could inhibit the development or expansion of microgrids in New York State.

Technical. The existing electrical and natural gas infrastructure in a community is the chief determinant of what is possible. All of the proposed loads in Liberty are on a single feeder. The extent of critical and important facilities on this feeder is unusual, and significantly lessens the complexity and cost of the electrical infrastructure required.

There is no natural gas infrastructure in Liberty, which forces the microgrid to rely on the limited solar PV arrays, battery storage, and intermittent use of a diesel backup generator for its energy supply in island mode. The availability of natural gas infrastructure is a major contributor to positive project feasibility. In communities without natural gas, generation is typically limited to solar PV and the tie in of existing backup generation, given the high costs of battery storage and biomass and the larger footprints required for wind. Given the intermittency of solar, and the capacity factor in New York State (approximately 14%), solar installations of a few hundred kW do not provide reliable generation for an islanded microgrid. In contrast, natural gas-fired generation provides a high reliability baseload, is relatively clean and efficient, and allows for cogenerated thermal sales if there is a proximate off-taker.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability and thermal off-takers are the leading elements of financially viable projects. Simply, natural gas generation is more cost efficient and provides highly reliable revenue streams through electricity sales, and offers thermal sales as an added revenue stream that is unavailable to a PV driven system. Given the currently high cost of battery storage options, it is difficult to make a compelling financial case for a small solar PV-battery system as a reliable baseload option. Unfortunately, here is no natural gas infrastructure in Liberty, and the project financial feasibility reflects this significantly higher cost and lower revenue.

Project financial structures are also important to consider. Revenue from these projects is driven almost exclusively by the sale of electricity and, if available, thermal energy sales; however, the microgrid control components may require a million dollars or more of capital investment. Ownership structures that separate cost drivers from the revenue streams may be difficult propositions, as the microgrid controls owners would have little opportunity to recoup their investment. This is especially true for privately owned microgrids in locations with reliable power supplies where islanding would be infrequent. In these cases, municipal ownership of the generation and infrastructure would be the most effective. The exception is if the entire microgrid can be developed "behind the meter." While it remains to be seen if utilities will allow this to transpire, a fully behind-the-meter solution in an area with moderate to high electricity prices would likely be a more advantageous financial proposition for connected facilities, as well as for generation and controls owners. Moreover, battery unit provided ancillary services have the potential to provide positive revenue for community microgrids.

Policy. State policy does not currently address community microgrids in a cohesive or holistic manner, nor have utility programs adequately recognized microgrid operations in their policies. DR is a potentially lucrative revenue stream in New York; however, current policies do not address microgrid DR participation. For instance, interpretations of the existing NYISO DR programs suggest that microgrids could take payments for islanding in times of high demand on the macrogrid. This scenario, while advantageous from a load shedding perspective, would also remove the microgrid connected generation simultaneously, leaving the macrogrid in a net-neutral position vis-a-vis the microgrid. While the nature of DR payments in such situations is not clear, the Project Team suggests explicit guidance from the NYPSC and the various utilities regarding their respective policies. Due to this lack of clarity, DR revenue has generally been excluded from the Project Team's revenue analysis.

Lastly, local community involvement is an important contributor to microgrid design success. Though even the most robust community engagement may not overcome unfavorable infrastructure, it is nonetheless imperative for steady forward progress. In Liberty, support from the utility for this effort has been strong and the community has been helpfully engaged. In other communities, as in Liberty, the Project Team has been in contact with administrators, elected officials, and non-governmental community representatives; this type of engagement is necessary to not only build support among prospective facilities but also to engage on ownership models, generation options, and other considerations that will directly affect the feasibility of the proposal. The engagement and commitment from the community is instrumental to the Project Team's ability to make recommendations that are acceptable and reasonable to the community. In those communities that are more removed from the process it is difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community.

Scalability. Scalability is governed by three factors. The structure of the electrical infrastructure, defined in the technical lessons learned section above, is a key factor to expansion of the microgrid. At some point of expansion, it becomes necessary to link multiple feeders, and having proximate feeders of the same voltage and connected to desirable facilities is an important criteria. Second, widespread AMI infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not microgrid participants. Liberty's microgrid is not an AMI remote disconnect based design; however, the utility of AMI is evident in other projects in the Project Team's portfolio. Lastly, the larger the microgrid grows, the more switches and controls are need to be installed, connected, and maintained for smooth islanding and grid-reconnect processes. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are also likely to push back if the microgrid grows to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the local utilities to find acceptable footprints that meet the goals of NYSERDA and respect the operational concerns of the utilities.

5.1.3 Stakeholder Lessons Learned

Developers. Many of the NY Prize project proposals require the Phase III award to achieve positive economics, and several more will remain in the red even with the grant. At this time there is no incentive for developers to participate in the build-out or operation of proposed microgrids that demonstrate negative returns. The potential for developer involvement is highest in communities with relatively high electricity prices and the presence of thermal off-takers; these conditions drive project profitability. Moreover, many of the municipalities are interested in part or full ownership of the projects, but either do not have available funds or lose the project economics without the available tax credits and incentives. In these situations, there may be opportunities for developers to leverage the tax benefits through design-build-own-operate arrangements.

Utilities. The Project Team often experienced problems with information flow. The Project Team would request information about feeders, switches, and other infrastructure from the utilities to inform the best possible microgrid design. However, the utilities were often guarded about providing the full data request in the absence of a design proposal, leading to something of a catch-22 in that neither party was able to adequately answer the request of the other without the desired information. These holdups were incrementally resolved to the satisfaction of both the Project Team and the utilities, but gathering data required significantly more time and dialogue than expected. The utilities may have been unprepared for the volume and detail of data requests from the Project Team, and the expected detail of the overall feasibility study may not have been fully communicated to each party.

Investor-owned-utilities in the Project Team's portfolio, including NYSEG in Liberty, were uniformly against allowing a third-party operational control of utility-owned infrastructure. This view is understandable, however it engenders a particularly difficult situation if the utility does not support the microgrid development. In such situations, the microgrid will generally be forced to construct duplicate infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. In general, utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive microgrid possibilities.

Academics. Academic considerations in microgrid development may center around three areas. First, research into a relatively small grid systems with multiple generators (some spinning, some inverter-based), temporally and spatially variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads. The second is optimizing financial structures for collections of distributed energy resources and control infrastructure. To-date, most microgrids in the United Stated have been campus-style developments in which the grid serves a single institution and can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust. Lastly, and related to financial structures, is the idea of how a "grid of grids" would be managed and structured to provide optimal operational support and the right mix of incentives to encourage customer and utility buy-in.

Communities. Engaged communities are important, but so too are realistic expectations of what a microgrid might include. Many communities expected dozens of facilities, or entire towns, to be included in the microgrid without understanding the limitations of the electrical and gas systems, the utility's operation requirements, or cost feasibility. While the Project Team worked with each community to assess and incrementally refine the facilities for inclusion, there is still much work to be done communicating the infrastructural realities of microgrid development. Setting expectations ahead of future microgrid initiatives will help communities begin with more concise and actionable goals for their community microgrids.

NYSERDA. NYSERDA awarded 83 Phase I feasibility studies, providing a wide canvas for jumpstarting microgrid development in the state but also placing administrative burdens on the utilities and on NYSERDA itself. As NYSERDA is aware, the timelines for receiving information from utilities were significantly delayed compared to what was originally intended, and this has impacted the ability of the Project Team to provide deliverables to NYSERDA on the original schedule. As mentioned in the Utilities Lessons Learned above, better communication between the State and the utilities may have preemptively alleviated this bottleneck.

Second, microgrid control infrastructure is expensive, and distributed energy resources require some scale to become revenue positive enough to subsidize the controls. Therefore, some NY Prize project proposals are not financially feasible without the NY Prize and myriad other rebate and incentive programs. In practical terms, this means that, while the NY Prize will create a body of knowledge around the development of community microgrids that did not previously exist, it is unlikely to spur unbridled growth of community microgrids in the State without policy changes. This is especially true in regions with relatively low electricity costs as well as power supply and reliability problems. Additionally, many communities that require improvements to the grid for reliability and resiliency and are lower income communities, which creates the added challenge of making them harder to pencil out financially as the community cannot afford to pay extra to ensure reliability. The projects with the least advantageous financials are often those needed most by the community. This gap is not easily bridged without further subsidization from the State.

5.2 Benefits Analysis

This section describes the benefits to stakeholders associated with the project. The microgrid will provide more resilient energy service, lower peaking emissions, ensure critical and important facilities remain operational during grid outages, and support the goals of New York's REV.

5.2.1 Environmental Benefits

New York State's normal energy portfolio is very clean, with primary energy sources being hydropower and nuclear. However, the Liberty microgrid is powered by a group of solar PV arrays and will decrease the overall emissions per kWh. Additionally, the solar PV arrays are cleaner than all peaking assets, which come online when statewide demand is high. The microgrid's generation assets will not exceed current New York State emissions limits for generators of their size and will not need to purchase emissions permits to operate.

5.2.2 Benefits to the Town of Liberty

Critical and important facilities in the Town of Liberty will receive resilient backup power from the proposed generation assets, ensuring they are available in outage situations and reducing the need for further investments in backup generation. The electricity generated with the solar PV arrays will also offset higher-emission peaking assets during peak demand events and lessen local diesel backup requirements. The Project Team met with the community by phone on March 3, 2016 to summarize the findings of the project and propose a recommended path ahead.

5.2.3 Benefits to Residents in and around Liberty

Residents of Liberty and the surrounding community stand to gain from access to a broad range of critical services anytime the microgrid is forced into islanded operation by an outage on the grid. Even if they are not formally connected to the microgrid, all residents of Liberty and nearby surrounding communities will have access to critical facilities and other important services in the event of an outage. In the future, the microgrid could be expanded to connect more facilities.

5.2.4 Benefits to New York State

New York State will benefit from the continued localization of energy resources, reducing load and congestion on the grid. Moreover, the expansion of distributed energy resources will further the goals of REV and provide a more resilient overall grid. A successful implementation of the Liberty microgrid will provide a proof of concept for the ownership and operation of a hybrid microgrid with local utility support. It will also demonstrate the utility of a large battery storage installation in support of a community microgrid, thus far only seen in more contained, campus microgrid settings. In addition, the lessons learned described in Section 5.1 are widely applicable to the further development of REV and future NY Prize efforts into Phase II and III.

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed Liberty microgrid is technically feasible and financially infeasible absent significant subsidies. The microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities.

The main barriers to completion will be obtaining funding for the project's capital costs and the negative annual returns. NYSEG must also agree to the new interconnection and electrical distribution network because it will incorporate NYSEG lines and switches. The Liberty Elementary School needs to agree to host the proposed solar arrays, battery units and backup diesel generator, and allow interconnection of the School's 70 kW solar arrays. Existing and proposed generation assets and microgrid components must be available for maintenance at all times. The Team is still working with the facilities to ensure that they will allow a third party to service the generation assets and microgrid components located on their land. The Project Team expects these operational challenges would be resolved by the time of construction—these facilities have considerable incentive to support the project, as construction and interconnection will guarantee a reliable power supply and possibly provide distributed energy resource asset owners with new sources of revenue.

The proposed Liberty microgrid would be a source of new operational information gleaned in operating a true community microgrid within the context of a hybrid ownership model, wherein a special purpose vehicle owns new DERs and the local utility, NYSEG, owns and operates the microgrid components/control infrastructure. Improved energy resilience enhances the local population's safety and quality of life during emergency outages, and local energy generation reduces the strain on the larger energy transmission and distribution infrastructure. Future expansion of the microgrid could maintain electric service to more facilities in Liberty, providing citizens with access to additional commercial and municipal services in outage situations.

This microgrid project will also help accelerate New York State's transition from traditional utility models to newer and smarter distributed technologies, and it will help achieve the REV goals of creating an overall more resilient grid, reducing load and congestion, expanding distributed energy resources, reducing GHG emissions, and constructing more renewable resources. It will also encourage citizens within the community to invest and get involved in local energy generation and distribution and will foster greater awareness of these issues.

Finally, the project will demonstrate the widely distributed benefits of microgrids paired with distributed energy resources. The utility will see increased revenues and grid performance, the community will reap the positive benefits of living in and around the microgrid, and commercial customers will benefit from the value of avoided outages.

Path Ahead

Absent NY Prize Phase III, and additional support, the project will not be financially feasible. However, the Community and the utility may use the Feasibility Study as a basis for improving energy resilience and reliability in the community absent a full microgrid implementation.

Expanded distributed energy resources within the footprint, even without smart controls and dedicated switches, will add more support for the grid and provide a positive value stream for the owner of the asset. If new assets are small and numerous enough, the net effect may be a footprint that has a wide mix of facilities that can remain online and functioning through an indefinite outage. The expansion of solar in the community need not be tied to a microgrid and if the specific roof orientation and size is advantageous, numerous firms will install PV arrays at no cost to the customer or facility. While this does not create a microgrid, it does stabilize, and often reduce, electricity bills and the benefits of these savings would be magnified in a relatively lower income community such as Liberty. The expansion of solar, particularly when 3rd party owned and financed, offers a no-regrets option to help close the energy affordability gap and should be looked upon favorably.

Beyond new DERs in the community, energy efficiency is the most cost effective way to bring down energy costs and in the event that a full microgrid is implemented in the future, decreases the required generation associated with it. NYSEG and NYSERDA have numerous programs available to customers, ranging from light-emitting diode (LED) upgrade rebates to full energy audits and thousands of dollars of support. These programs are not restricted to the microgrid footprint and a wide push across the Town could materially reduce energy costs and increase the financial security and discretionary spending power of town residents. Within the microgrid footprint, the Project Team estimates approximately 20 kW of available efficiency savings, saving a potential $15,000/year in electricity costs.

Appendix A – Load Profiles and One-Lines

The Project Team obtained monthly metering data for the Town Government Center and Liberty Elementary School from NYSEG and estimated monthly data for other facilities. The following 24 hour load curves represent simulations based on facility type and estimated monthly load factor (ratio of peak to average demand). They are included in this feasibility study to show which facilities have highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid.

REDACTED PER NDA WITH NYSEG

Appendix B – Legal and Regulatory Commentary

The Liberty microgrid, as proposed in this document, exists with the consent and support of NYSEG and within the Project Team's understanding of current regulatory and legal considerations. The proposed microgrid exists as a set of generation assets that will sell electricity to NYSEG via a long term PPA, providing load agnostic support to the NYSEG grid. However, the project must unlock new sources of revenue to become commercially feasible. One avenue of potential revenue is leveraging the batteries to effectively manage time of use (TOU) billing cycles and reduce peak demand charges for the entire microgrid. These uses of the battery units would require the microgrid to operate in island mode continuously and interact with NYSEG as a single entity behind a single meter. The two principal regulatory barriers to this business model are current New York State policies regarding electric corporations[80] and the possibility that NYSEG will not allow the microgrid to subscribe to TOU billing as a single entity.

Continuous operation in islanded mode may cause the microgrid to be regulated as an electric corporation under NYPSC Public Service Law (PSL). The heavy regulation placed upon electric corporations would discourage investment and increase overall project management costs. The microgrid has two avenues to avoid regulation as an electric corporation: becoming a "qualifying facility (QF)" under the terms of PSL §§ 2(2-d), or waiting for a change in State and Federal utility regulations (such as the Federal Public Utility Regulatory Policies Act).

The financial viability of many community microgrids would be significantly enhanced if the NYPSC were to include them as eligible for QF designation. This designation would allow community microgrids to operate as a single autonomous entity, managing electricity generation and sales independently from the larger grid. Under current NYPSC law, Qualifying Facilities must meet certain tests regarding generation type and size, distance, and number of users. The Liberty microgrid meets most of these standards, as it is primarily solar-powered, connects proximate facilities (two miles or less),[81] and has an overall generation capacity well below 80 MW.

However, the project does not meet the number of users test. In *Burrstone*, petitioners raised the question of whether a qualifying facility may distribute power to three different institutional users – a hospital, college, and nursing home. The Commission found that "furnishing electric service to multiple users" is specifically contemplated in PSL §2(2-d) "by providing that electricity may be distributed to 'users,' in the plural."[82] The Burrstone Energy Project was held to qualify for regulatory exemption. The *Burrstone* case is the only existing precedent of the Commission applying the "qualifying facility" standard to more than one user. One interpretation of this precedent might conclude that no upper bound exists on the number of users that may be

[80] PSL § 65, PSL § 66, PSL § 68(a), and PSL §69.
[81] Case 93-M-0564.
[82] Case 07-E-0802 - Burrstone Energy Center LLC – Petition For a Declaratory Ruling That the Owner and Operator of a Proposed Cogeneration Facility Will Not Be Subject to Commission Jurisdiction (August 28, 2007).

served by a qualifying facility. This interpretation, however, may prove unwisely speculative. The Liberty microgrid will include six facilities and four groups of residential and commercial loads, and may therefore have to wait for State and Federal utility laws to ease the regulatory burden on community microgrids.

Using NYSEG's infrastructure to continuously operate the microgrid in island mode may present another obstacle to unlocking TOU bill management revenue streams. NYSEG may not allow the microgrid to operate existing distribution infrastructure independently from the larger grid. Microgrid owners may have to remit payment to NYSEG or develop a contract agreement with NYSEG that would allow continuous operation as a single, behind the meter load.

State and Federal utility laws do not currently incentivize community microgrids because there is no legal precedent for the concept. However, widespread penetration of community microgrids into the current utility system would improve the operation of the NYISO system by matching local load with distributed energy resources and possibly reducing congestion on major transmission infrastructure. Investor-owned utilities are well positioned to serve as the distributed system platform in their service territories to integrate multiple microgrids, aggregate excess generation capacity, and redistribute services to voltage or watt deficient microgrids, municipal grids, and load pockets. IOUs therefore are unlikely to oppose new laws that encourage widespread microgrid development, as it would benefit both the utilities and the state to integrate IOUs into the future microgrid landscape.

Easing regulation of community microgrids is necessary to achieve New York State's vision of a "grid of grids." The Project Team believes energy costs and the current condition of electricity infrastructure in New York State will promote an economically efficient expansion of a system of microgrids, provided that regulation is eased. It is therefore not unlikely that community microgrids may gain more operational freedom and could unlock several new value streams in the future. However, for the purposes of this feasibility study, the Project Team has assumed a conservative base case that functions within the existing regulatory environment.